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Research Memorandum GD-68

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RESEARCH MEMORANDUM

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December 2003

ICT and Europe's Productivity Performance
Industry-level growth account comparisons with the United States

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Abstract
In this paper we present a new industry-level database to analyse sources of growth in four major European countries: France, Germany, Netherlands and United Kingdom (EU-4), in comparison with the United States for the period 1979-2000. Aggregate labour productivity growth is decomposed into industry-level contributions of labour quality, ICT and non-ICT capital deepening and TFP. A small set of service industries is mainly responsible for the acceleration in ICT capital deepening in both regions, but their contribution to growth is lower in the EU-4 than in the U.S. TFP in these industries accelerated in the U.S in the 1990s, but not in Europe. In addition, widespread deceleration in non-ICT capital deepening in the EU-4 has led to a European productivity slowdown. This is linked to wage moderation in the 1990s.

Acknowledgments: This research was supported by a grant from the European Commission (DG Enterprise) for a study on "Performance Analysis of the EU Economy from the Point of View of its Industrial Sectors" (see O'Mahony and van Ark, 2003) with an additional contribution from the UK Treasury 'Evidence Based Policy Fund'. The authors thank Colin Webb (OECD) for his advice on the use of the OECD STAN database. We received data series and advice on their use from employees at various national statistical offices: the Federal Statistical Office in Germany, Statistics Netherlands, the Office for National Statistics (U.K.), the Bureau of Economic Analysis (U.S.), and the Bureau of Labor Statistics (U.S.). We also like to thank Martin Falk (WIFO) and Lawrence Nayman (CEPII) for supplying data. We have benefitted from discussion with our colleagues at NIESR and Groningen and from Nicholas Oulton and Salya Srinivasan. The authors are solely responsible for the results and analysis in this paper.

1. Introduction

The late 1990s has seen a major change in the comparative growth performance of Europe and the United States. Since the Second World War labour productivity growth in Europe had outstripped that of the United States, leading to rapid catch-up. However, since 1995 U.S. labour productivity growth has nearly doubled compared to earlier periods, while European growth rates declined.

Much research based on growth accounting has focused on explaining the U.S. growth surge, as well as why Europe has fallen behind. The first round of studies focused on analysing aggregate trends in the U.S. Accelerating labour productivity growth was mainly attributed to increasing investment in ICT-goods and improvements in aggregate TFP (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000). Industry-level TFP trends were still unavailable, but rough estimates by "backing out" TFP growth in IT production suggested that most of the aggregate TFP acceleration could be traced back to rapid technological change in ICT goods production.[1] But as more detailed industry-level data became available the focus broadened to include not only ICT-goods producing industries but also service industries that are heavy users of ICT. Studies by Bosworth and Triplett (2003) and Jorgenson, Ho and Stiroh (2002) show that the biggest contributors to aggregate ICT capital deepening are a limited number of service industries, in particular trade, finance and business services. Besides TFP growth in ICT-goods manufacturing, TFP acceleration in the ICT-using service industries appears to be important as well.

The first set of growth accounting studies for Europe relied heavily on private data sources on ICT expenditure collected outside the system of national accounts (Schreyer 2000, Daveri 2001). They found that although ICT-investment *growth* also accelerated in Europe, its lagging behind the U.S. was mainly due to lower *levels* of ICT investment. This conclusion was confirmed by studies using genuine investment series from national accounts data (Colecchia and Schreyer 2002, van Ark, Melka, Mulder, Timmer and Ypma 2002, Vijselaar and Albers 2002). Typically, they found that the contribution of ICT capital deepening to aggregate labour productivity growth in Europe was only half the contribution in the U.S.

Secondly, the studies unveiled that the European slowdown after the mid 1990s was not directly related to developments in information and communication technology and hence was frequently overlooked. In contrast to the U.S., contributions from non- ICT capital deepening declined considerably after 1995 and appeared to be an important determinant of the European labour productivity slowdown (Timmer, Ypma and van Ark 2003).

Thirdly, it was found that in contrast to the U.S., aggregate TFP growth in Europe did not accelerate. This difference could only partly be attributed to the smaller ICT-producing sector in Europe compared to the U.S. and hence must be sought elsewhere in the economy (Timmer, Ypma and van Ark 2003). A detailed study of labour productivity growth at the

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[1] The latter point is stressed especially by Gordon (2000). Bosworth and Triplett (2003) and Jorgenson, Ho and Stiroh (2002) show that this "backing out" of IT-production TFP from aggregate TFP can be highly misleading as it generates only a *net* measure of TFP growth outside IT-production. Industry-level studies show that TFP growth rates outside IT-goods manufacturing have also been high. However, high growth in some industries was cancelled out by low or negative TFP growth in many other industries, see section 5.

industry level by van Ark, Inklaar and McGuckin (2003b) suggested that much of the failure of Europe to achieve its own labour productivity growth revival in the late 1990s can be traced to the same industries that performed so well in the United States, particularly trade and finance. Labour productivity growth in these intensive ICT using industries lagged severely in Europe.

However, without detailed information on ICT and non-ICT investment for individual industries, it remains unclear which industries are responsible for the gap in ICT investment between Europe and the U.S., the European slowdown in non-ICT capital deepening and its sluggish TFP growth compared to the U.S. The main novelty of this study is the incorporation of ICT and non-ICT capital service flows in a growth accounting decomposition of labour productivity growth at the industry level for European countries. This is done for twenty-six industries and four major European countries (France, Germany, the Netherlands and the U.K.) in comparison with the U.S. for the period from 1979 to 2000. Together these four countries make up about 70 percent of total GDP in the European Union and are referred to as EU-4 in the remainder of this paper.

Table 1 provides a decomposition of aggregate labour productivity growth into the contributions from labour quality, ICT and non-ICT capital deepening and TFP growth for EU-4 and the U.S. The results in Table 1 reflect previous findings on comparative EU and U.S. performance discussed above. The main source of the EU-4 slowdown is a deceleration of non-ICT capital deepening and, in contrast to the U.S., a lack of acceleration of TFP growth. Although in this paper we mostly focus on the EU-4 versus the U.S., it is important to realise that in some cases the EU-4 results hide considerable cross-country variation. In Figure 1 we show the decomposition of labour productivity growth for the individual European countries as well as the EU-4 and U.S. Although the individual countries differ in their growth experience, a few common observations stand out. First of all, all European countries had higher labour productivity growth than the U.S. before 1995 and all except the U.K. had lower growth after 1995. Furthermore, the contribution of ICT capital deepening is lower than in the U.S. in all European countries throughout the period. It is beyond the scope of the paper to fully discuss the individual country results, but in cases where some or more of the European countries diverge considerably from the EU-4 results, these will be pointed out.

The rest of the paper is organised as follows. In the next section we describe the data and methods used in constructing our industry growth accounting database, focusing in particular on the derivation of the investment series. It also describes the method to derive the contributions of industry-level capital deepening and TFP growth to aggregate labour productivity growth, which is the main focus of this study. Next we characterize labour productivity growth by grouping industries that produce ICT goods and services, those that intensively use ICT and those that do not. Subsequent sections in turn consider the components that make up labour productivity growth: ICT investment, TFP growth, labour quality and non-ICT investment. In Section 4 we show that the industries responsible for ICT capital deepening are the same in the EU and the U.S and ICT investment has been growing at a similar pace. However, the contribution to aggregate labour productivity growth is lower in almost all EU industries due to smaller ICT stocks. TFP growth is analysed in Section 5. Both the EU and the U.S. enjoyed accelerating TFP growth in ICT producing industries.

Table 1, Sources of labour productivity growth in the EU-4 and the United States, 1979-2000

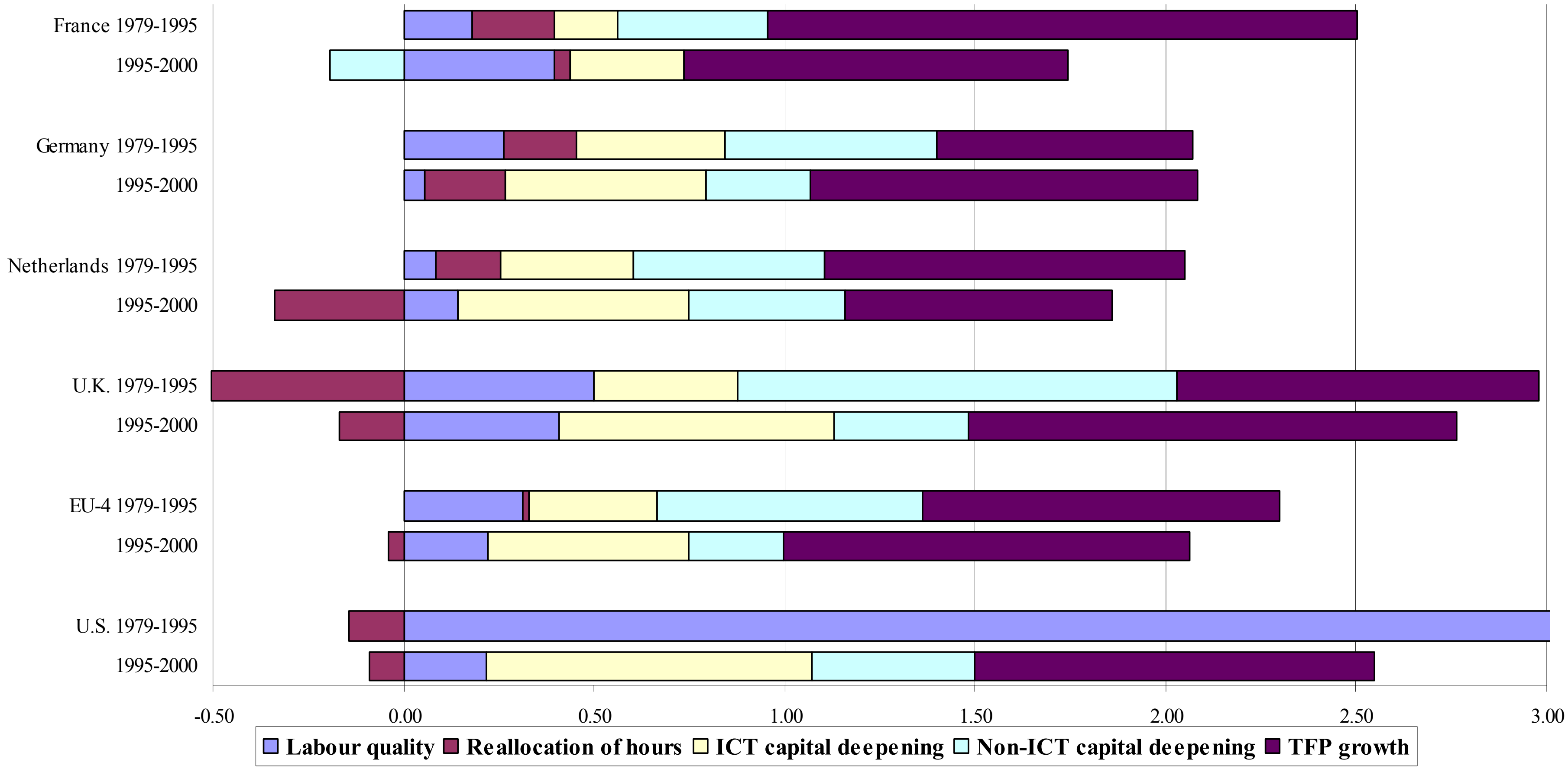
	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Labour productivity	2.30	1.21	-1.09	2.02	2.46	0.43	-0.27	1.25	1.52
Contribution of									
Labour quality	0.31	0.28	-0.03	0.22	0.22	-0.01	-0.09	-0.07	0.02
Reallocation of hours	0.02	-0.15	-0.16	-0.04	-0.09	-0.05	-0.06	0.05	0.11
ICT capital deepening	0.33	0.46	0.12	0.53	0.86	0.33	0.19	0.40	0.21
Non-ICT capital deepening	0.70	0.35	-0.35	0.25	0.43	0.18	-0.45	0.08	0.53
TFP growth	0.94	0.26	-0.67	1.07	1.05	-0.02	0.13	0.79	0.66

Notes: EU-4 includes France, Germany, Netherlands and U.K., which makes up 70% of EU-15 GDP

Labour productivity growth is defined as the growth in real value added per hour worked. Labour quality takes account of changes in the skill composition of the workforce. Reallocation of hours reflects shifts in employment to or from high productivity industries. Capital deepening is the change in capital services per hour worked (see Section 2).

Source: see Appendix A

Figure 1, Sources of labour productivity growth in Europe and the United States, 1979-2000



Source: see Appendix A

But only in the U.S. the contribution of ICT intensive industries, such as trade and finance, accelerated in the mid 1990s. During 1995-2000 aggregate TFP growth in the EU still kept up with the U.S. but only because of higher contributions from industries that are neither ICT producers, nor intensive ICT users. In Section 6 we look at the role of labour quality. The contribution in both the EU and the U.S. decreased slightly in the second half of the 1990s and major differences in the contributions between the two regions, or over time, were not found. In Section 7 it is shown that the deceleration in non-ICT capital deepening in Europe is widespread. Our results show that nearly every European industry exhibits a deceleration in non-ICT capital deepening, but about half of the deceleration can be traced to mining and manufacturing industries. Another quarter is due to slower investment in non-ICT assets in business services. In Section 8 we offer a first explanation for this by looking at developments in wages and rental prices. Moderated wages appeared to have induced a substitution of labour for non-ICT capital in many industries. Section 9 provides comparisons of the results of this study with similar industry decomposition studies for the U.S. and the U.K. Section 10 concludes.

2. Data and methods

Data

In this paper we use a database on output and labour and capital inputs for 26 industries in France, Germany, the Netherlands, the United Kingdom and the United States, covering the period 1979 to 2000. The database is available at www.niesr.ac.uk/epke/ and http://www.ggdc.net/dseries/IGA.shtml and will be regularly updated. In this section we give a brief overview of the sources and methods used to construct this database. More detailed information on sources and methods can be found in Appendix A.

Our output measure is value added at constant prices and is based on the GGDC 60-industry database. This database is constructed from detailed national accounts as compiled in the OECD STAN database and from industrial and business surveys.[2] Deflators for ICT producing manufacturing industries have been harmonised across countries as discussed below.

Labour input is measured as hours worked. The total number of hours worked is calculated as the total number of persons employed (including self-employed) times the average number of hours worked and are taken from the 60-industry database. In addition, for each country we distinguish between several different types of labour based on educational attainment. To avoid having to force different educational systems into a common classification, the number of labour types per country varies between three in Germany and seven in the Netherlands. Information on the share of each labour type in total employment and their shares in total labour compensation is drawn from national labour force surveys. We

[2] For the most recent version of the 60-industry database as well as detailed descriptions of sources and methods, see www.ggdc.net.

apply the employment shares by type to the total number of hours worked and the compensation shares to total labour compensation from the 60-industry database.[3]

To construct our capital input measure we use data on investment in current and constant prices for six asset types. Of these assets, three refer to ICT goods (computers, communication equipment and software) and three to non-ICT goods (transport equipment, other (non-ICT) machinery and equipment and non-residential structures).[4] Residential buildings are not taken into account to allow for a sharper focus on the productivity contribution of business-related assets. Since most of the outputs and inputs of the real estate industry consists of housing and imputed rents from housing we have to make an adjustment for this. However, it is hard to separate imputed rents only, so we decided to leave out the real estate industry from both outputs and inputs. [5]

In the case of France, the Netherlands and the U.S., these investment data are based on detailed files from the national statistical offices, which are not published as part of the regular national accounts. However, the data are consistent with total investment by industry and total investment by asset from the national accounts. In the case of Germany and the U.K., derivation of complete investment series required the use of data from secondary sources such as input-output investment flow matrices or dedicated investment surveys. The starting year for our investment data differ by country, beginning as early as 1901 in the United States and as late as 1970 in Germany. O'Mahony (1999) provides data on capital stocks for long-lived assets such as non-residential structures up to the year in which the investment data start, with the exception of the Netherlands and the U.S. For the Netherlands, the initial capital stocks are already part of the detailed industry by asset investment data. In the case of the U.S., the available data from 1901 onwards should be sufficient to get reliable capital stock estimates for all assets for the 1979-2000 period.

Calculating capital stocks and rental prices

To estimate capital stocks we also need depreciation rates. For this we rely on industry-specific geometric depreciation rates for detailed assets in the United States, originally from Fraumeni (1997) and Jorgenson and Stiroh (2000), applied to all countries (see Appendix A for details). Capital stocks are then constructed using the perpetual inventory method (PIM):

$$K_{j,t} = (1-\delta_j)K_{j,t-1} + I_{j,t}, \tag{1}$$

where $K_{j,t}$ is the capital stock of asset j at time *t*, δ_j is the depreciation rate of asset j and $I_{j,t}$ is investment at constant prices. Following the methodology pioneered by Jorgenson

[3] Labour compensation includes wages and salaries as well as supplements such as social security payments. Labour compensation of self-employed is imputed. See Appendix A for details.

[4] In the case of the Netherlands, there is currently no data on investment in communication equipment by industry, so ICT assets only include computers and software.

[5] In some cases, industries other than real estate also invest in residential buildings, such as the insurance industry in the Netherlands or the government industry in the U.S. It is not clear how these residential buildings are accounted for on the output side of these industries, so we only remove residential investment without making further adjustments.

and Griliches (1967) and more recently implemented in Jorgenson, Ho and Stiroh (2002) we calculate rental prices for each asset:

$$r_{j,t} = R_t + \delta_j - \dot{p}_{j,t} \tag{2}$$

The rental price is defined as the rate of return *R* at time *t* plus the depreciation rate minus the rate of inflation of the asset in question. We assume the rate of return to be the same across industries and equal to the internal rate of return for the total economy.

In contrast to Jorgenson *et al.* (2002) we abstract from capital taxation in our formulation of the rental price. Although this introduces a bias in our calculations, this will be relatively small given the low and declining capital taxation rates. We also differ from Jorgenson *et al.* (2002) in terms of the scope of our capital input concept. We have chosen to focus on investment in fixed reproducible assets as distinguished in the System of National Accounts (1993), with the exception of residential buildings, which we exclude. Jorgenson *et al.* (2002) on the other hand does include residential buildings, as well as land, inventories and consumer durables as capital assets. Land and inventories are added as regular assets to all industries and will only have an impact on the contribution of capital deepening. In the case of consumer durables and residential buildings, the rental value of the assets is allocated to a separate household industry.

Growth accounting

Data on output and inputs are combined in a growth accounting system, originating with Solow (1957) and further developed in Griliches and Jorgenson (1967) and Jorgenson, Gollop and Fraumeni (1987), whereby the growth of output is attributed to growth in inputs and a residual, generally referred to as total factor productivity (TFP). Under the assumptions of well-measured inputs, perfect mobility of inputs across industries, perfect competition and constant returns to scale it measures the shift in the production possibility frontier.[6] In this database we do not allow for a separate role for intermediate inputs, as the required input/output tables to do so are not yet available for all countries. This means our TFP measure is based on value added instead of gross output.[7]

In the growth accounting system, inputs are assumed to earn their marginal products, so the compensation share of an input in total value added is equal to the output elasticity of that input. This means growth of output of each industry can be decomposed as follows:

$$\Delta \ln Y_t = \bar{v}_t^L \Delta \ln L_t + \bar{v}_t^K \Delta \ln K_t + \Delta \ln TFP_t \tag{3}$$

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[6] Other frequently used terms are technological change, multi-factor productivity, the Solow residual and "measure of our ignorance". See Hulten (2001) for an overview as well as caveats to the interpretation of TFP as a measure of technical progress. See for example Basu, Fernald and Shapiro (2002) for possible adjustments to TFP to take into account variable input utilization and imperfect competition.

[7] As for example Jorgenson *et al.* (2002) show, the value-added TFP measure can be converted into a gross output TFP measure using information on the share of value added in gross output.

where $\Delta \ln Y_t$ is growth of real gross value added, $\Delta \ln L_t$ is growth of labour input and $\Delta \ln K_t$ is growth of capital input (we omit the industry subscript here). $\bar{v}_t^L$ is the two period average share of labour compensation in nominal value added and $\bar{v}_t^K$ the share of capital compensation in nominal value added. Because of constant returns to scale: $\bar{v}_t^L = 1 - \bar{v}_t^K$.

Input growth rates are given by growth in each labour type (1,…,h) and each capital type (1,…,j) weighted by their two period average share in total nominal input compensation:

$$\Delta \ln L_t = \sum_h \bar{v}_{h,t}^L \Delta \ln L_{h,t} \tag{4}$$

$$\Delta \ln K_t = \sum_j \bar{v}_{j,t}^K \Delta \ln K_{j,t} \tag{5}$$

$$\text{with } \bar{v}_{h,t}^L = \frac{1}{2}\left(\frac{w_{h,t} L_{h,t}}{\sum_h w_{h,t} L_{h,t}} + \frac{w_{h,t-1} L_{h,t-1}}{\sum_h w_{h,t-1} L_{h,t-1}} \right) \tag{6}$$

where $w_{h,t}$ and $L_{h,t}$ are respectively the wage (labour cost per hour) and number of hours worked by labour type *h* at time *t*. $\bar{v}_t^L$, the labour share in value added from (3) can now be rewritten as

$$\bar{v}_t^L = \frac{1}{2}\left(\frac{\sum_h w_{h,t} L_{h,t}}{Y_t} + \frac{\sum_h w_{h,t-1} L_{h,t-1}}{Y_{t-1}} \right) \tag{7}$$

with Y_t nominal value added at time t. The weight of each capital asset is defined analogously as:

$$\bar{v}_{j,t}^K = \frac{1}{2}\left(\frac{r_{j,t} K_{j,t}}{\sum_j r_{j,t} K_{j,t}} + \frac{r_{j,t-1} K_{j,t-1}}{\sum_j r_{j,t-1} K_{j,t-1}} \right) \tag{8}$$

Here $r_{j,t}$ is the rental price from equation (2) and $K_{j,t}$ the nominal capital stock of asset type j. $\bar{v}_t^K$, the capital share in value added from (3) can now be rewritten as

$$\bar{v}_t^K = \frac{1}{2}\left(\frac{\sum_j r_{j,t} K_{j,t}}{Y_t} + \frac{\sum_j r_{j,t-1} K_{j,t-1}}{Y_{t-1}} \right). \tag{9}$$

As in Jorgenson, Gollop and Fraumeni (1987), we define labour quality growth ($\Delta \ln q_t^L$) as the difference between the growth of our labour input and the growth of total hours worked:

$$\Delta \ln q_t^L = \sum_h \bar{v}_{h,t}^L \Delta \ln L_{h,t} - \Delta \ln \sum_h L_{h,t} = \Delta \ln L_t - \Delta \ln H_t \tag{10}$$

Here we define L_t as in equation (4) and H_t as the sum of hours over the different labour types. By rearranging equation (3) the results can be presented in terms of average labour productivity growth defined as $y = Y/H$, the ratio of output to hours worked, $k = K/H$, the ratio of capital services to hours worked, labour quality and TFP. Subtracting $\Delta \ln H_t$ from both sides of equation (3) and using (10) then gives:

$$\Delta \ln y_t = \bar{v}_t^L \Delta \ln q_t^L + \bar{v}_t^K \Delta \ln k_t + \Delta \ln TFP_t \tag{11}$$

For the purpose of this study we distinguish between two sets of capital goods: ICT assets and non-ICT assets. Let *N* be the set of non-ICT assets and let *ICT* be the set of ICT assets. Using (5), equation (11) can be rewritten as:

$$\Delta \ln y_t = \bar{v}_t^L \Delta \ln q_t^L + \bar{v}_t^K \left(\sum_{j \in ICT} \bar{v}_{j,t}^K \Delta \ln k_{j,t} + \sum_{j \in N} \bar{v}_{j,t}^K \Delta \ln k_{j,t} \right) + \Delta \ln TFP_t \tag{12}$$

Now define ICT capital deepening as $\Delta \ln k_t^{ICT} = \sum_{j \in ICT} \bar{v}_{j,t}^{ICT} \Delta \ln k_{j,t}$, where the growth in ICT capital stocks is weighted by the share of capital compensation in total ICT capital compensation:

$$\bar{v}_{j,t}^{ICT} = \frac{1}{2} \left(\frac{r_{j,t} K_{j,t}}{\sum_{j \in ICT} r_{j,t} K_{j,t}} + \frac{r_{j,t-1} K_{j,t-1}}{\sum_{j \in ICT} r_{j,t-1} K_{j,t-1}} \right) \tag{13}$$

The share of capital compensation of non-ICT assets in total non-ICT capital compensation is defined analogously. Equation (12) can now be simplified to:

$$\Delta \ln y_t = \bar{v}_t^L \Delta \ln q_t^L + \bar{v}_t^{ICT} \Delta \ln k_t^{ICT} + \bar{v}_t^N \Delta \ln k_t^N + \Delta \ln TFP_t \tag{14}$$

where

$$\bar{v}_t^{ICT} = \frac{1}{2}\left(\frac{\sum_{j \in ICT} r_{j,t} K_{j,t}}{Y_t} + \frac{\sum_{j \in ICT} r_{j,t-1} K_{j,t-1}}{Y_{t-1}} \right) \tag{15}$$

Once again $\bar{v}_t^N$ is defined analogously. Equation (14) shows the four different sources of industry labour productivity growth, namely labour quality growth, ICT capital deepening, non-ICT capital deepening and TFP growth. With this decomposition we can now turn to the subject of aggregation across industries.

Aggregation

There are a number of ways to aggregate output and inputs across industries. Each of these methods corresponds to different assumptions regarding relative price movements of output and inputs across industries. Jorgenson, *et al.* (2002) distinguish three methods, namely the *aggregate production function*, the *aggregate production possibility frontier* and *aggregation over industries*. If an aggregate production function exists, the price of a unit of value added has to show the same evolution over time across all industries. Under that assumption, value added at constant prices can simply be summed across industries. This is relaxed under the assumption of an aggregate production possibility frontier, which only requires that inputs deliver the same marginal product across industries. In that case, inputs can be summed across industries. The weakest assumption is used when aggregating over industries as in that case input prices could also differ across industries for example due to the lack of perfect factor mobility. In that case, the price of each input and output is assumed to reflect its marginal productivity.[8] In this paper we employ the third method, which means that we weight industry growth rates of output and inputs by their share in aggregate value added to calculate the contributions as in Table 1 and subsequent tables.

To facilitate the comparison between our four European countries and the United States we calculate an aggregate of the four European countries, which we refer to as EU-4. Although this aggregate leaves out important EU countries such as Italy and Spain, besides numerous smaller EU countries, we believe that with coverage of 70 percent of EU-15 GDP we can draw conclusions that are likely to carry over to the total EU.[9] Since output prices of each industry generally differ across countries we use industry-specific purchasing power parities (PPPs) to aggregate value added at current prices across the EU-4.[10] These are also used to aggregate labour and capital compensation. Growth of output and inputs are then aggregated across countries in a similar fashion as aggregation across industries.

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[8] The plausibility of the assumptions of equal prices can be evaluated by comparing aggregate growth when summing output and inputs across industries with growth calculated as a Törnquist-weighted average of industry growth rates. Jorgenson, *et al.* (2002) refer to this as the reallocation of value added. Similarly, reallocations of labour and capital inputs can be calculated. As in Jorgenson, *et al.* (2002), we find that while the reallocation of value added is reasonably large, the other reallocations are comparatively small.

[9] See also Inklaar, O'Mahony, Robinson and Timmer (2003a) for labour productivity growth results for the full European Union based on the 60-industry database. The growth patterns of the EU-4 are broadly representative of the full EU-15, although the slowdown after 1995 is larger for the EU-15 than for the EU-4.

Industry contributions to aggregate labour productivity growth

In the remainder of this paper we will focus mainly on the contribution of industry capital deepening, labour quality growth and TFP growth on aggregate labour productivity growth. Appendix Tables B.17-28 show the decomposition of equation (14) for all countries and industries. Let *i* denote industries and growth of aggregate GDP (Y_t) be defined as a Törnqvist weighted industry value added growth as follows:

$$\Delta \ln Y_t = \sum_i \bar{v}_{i,t}^Y \Delta \ln Y_{i,t} \tag{16}$$

where $\bar{v}_i^Y$ is the two period average share of industry *i* in aggregate value added:

$$\bar{v}_{i,t}^Y = \frac{1}{2}\left(\frac{Y_{i,t}}{\sum_i Y_{i,t}} + \frac{Y_{i,t-1}}{\sum_i Y_{i,t-1}} \right) \tag{17}$$

Also define total aggregate hours worked as the sum over all industries: $H_t = \sum_i H_{i,t}$.

The conventional way of calculating aggregate labour productivity growth is to divide aggregate real value added growth by the growth in total hours worked ($\Delta \ln y_t = \Delta \ln Y_t - \Delta \ln H_t$). As shown by Stiroh (2002b), aggregate labour productivity growth can then be decomposed as follows:

$$\Delta \ln y_t = \sum_i \bar{v}_{i,t}^Y \Delta \ln y_{i,t} + \left(\sum_i \bar{v}_{i,t}^Y \Delta \ln H_{i,t} - \Delta \ln H_t \right) = \sum_i \bar{v}_{i,t}^Y \Delta \ln y_{i,t} + R \tag{18}$$

The term in brackets in equation (18) is the reallocation of hours and reflects differences in the share of an industry in aggregate value added and its share in aggregate hours worked. This term will be positive when industries with an above-average labour productivity level show positive employment growth or when industries with below average labour productivity have declining employment shares.

Using equations (15), (16) and (18) and omitting the time subscript for convenience, the full decomposition of aggregate labour productivity growth can be written as

$$\Delta \ln y = \sum_i \bar{v}_i^Y \left(\bar{v}_i^L \Delta \ln q_i^L + \bar{v}_i^{ICT} \Delta \ln k_i^{ICT} + \bar{v}_i^N \Delta \ln k_i^N + \Delta \ln TFP_i \right) + R \tag{19}$$

In this way, the contribution of input and TFP growth from each industry to aggregate labour productivity growth can be calculated. For example, the contribution of ICT-capital deepening in industry *i* to aggregate labour productivity growth ($LPCON_i^{ICT}$) is given by

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[10] See Inklaar et al. (2003) for a description of the construction of these PPPs.

$$LPCON_i^{ICT} = \bar{v}_i^Y \left(\bar{v}_i^{ICT} \Delta \ln k_i^{ICT} \right) \tag{20}$$

which is the growth of ICT capital per hour worked in industry *i* weighted by the share of ICT capital compensation in industry *i* in aggregate nominal value added. The weight is the product of the share of industry *i* in aggregate value added ($\bar{v}_i^Y$) and the share of ICT capital compensation in industry value added ($\bar{v}_i^{ICT}$).

Similarly the contribution to aggregate labour productivity growth from non-ICT capital deepening ($LPCON_i^N$) is given by the growth of non-ICT capital per hour worked in industry *i* weighted by the share of non-ICT capital compensation in industry *i* in aggregate nominal value added:

$$LPCON_i^N = \bar{v}_i^Y \left(\bar{v}_i^N \Delta \ln k_i^N \right) \tag{21}$$

The contribution to aggregate labour productivity growth from labour quality ($LPCON_i^q$) is given by:

$$LPCON_i^q = \bar{v}_i^Y \left(\bar{v}_i^L \Delta \ln q_i^L \right) \tag{22}$$

which is the growth of labour quality in industry *i* weighted by the share of labour compensation in industry *i* in aggregate nominal value added. The weight is the product of the share of industry *i* in aggregate value added and the share of labour compensation in industry value added ($\bar{v}_i^L$).

Finally, the contribution to aggregate labour productivity growth from TFP growth ($LPCON_i^{TFP}$) is given by

$$LPCON_i^{TFP} = \bar{v}_i^Y \Delta \ln TFP_i \tag{23}$$

which is the growth of TFP in industry *i* weighted by the share of industry *i* in aggregate value added.

Deflation of ICT goods

Another issue is the deflation of ICT goods. It is well known that the capabilities of semiconductors and computers have improved tremendously over the past few decades.[11] Since consumers can buy computers with vastly more computing power at comparable prices, the price of computing power has declined continuously. However, traditional methods of sampling and calculating price indices for these goods will almost certainly underestimate the rate of price decline. At present there are only a few countries, like the U.S., that have an adequate system in place for measuring prices of computers and semiconductors. This means that measured ICT output and ICT investment growth in all other countries is likely to be biased downwards. Using a method that mirrors Schreyer's (2000, 2002) "harmonisation" method we (partly) avoid this bias. This involves applying U.S. deflators to the ICT producing manufacturing industries in European countries. Within electrical and electronic equipment and instruments (ISIC 30-33) the 60-industry database distinguishes eight separate industries, amongst them computers, communication equipment and semiconductors manufacturing. We apply U.S. double-deflated value added deflators to each of these industries separately after making a correction for the difference in the general rate of inflation in the U.S. and the European country under consideration. We then aggregate the harmonised deflators for each of the eight industries using the European country's value added structure. In the case of investment deflators, we calculate (industry-specific) investment goods deflators for computers, communication equipment and software for the U.S. and apply these to all other countries after making a correction for the general inflation level.[12]

3. Labour Productivity growth: ICT producing, ICT using and non-ICT industries

To simplify the exposition of our results, we distinguish between industries that produce ICT goods or services, those that use ICT intensively and those that use ICT less intensively (henceforth referred to as non-ICT industries). Previous research has shown that this distinction is useful as these groups of industries do not only differ in terms of their ICT-intensity, but also in their pattern of productivity growth (Stiroh 2002b; van Ark, Inklaar and McGuckin 2003b). We use adopt the classification used in previous research but given the

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[11] See Nordhaus (2001) for a long-term perspective on the increase in computing power and Doms (2003) for an overview of technical progress and price declines in the production of communication equipment.

[12] In the case of industry deflators, the general inflation level is measured as the deflator of all industries except the ICT producing manufacturing industries. For investment deflators, the inflation level is defined as the price change of non-ICT investment goods.

level of detail in our database, some compromises must be made. We classify electrical and optical equipment (ISIC 30-33) and post and telecommunication services (ISIC 64) as ICT producing. Retail and wholesale trade, finance, business services and a small number of manufacturing industries are classified as ICT using. These industries all had high shares of ICT capital compensation in value added in both the EU-4 and the U.S.[13] Appendix Table A1 provides the complete classification of the 26 industries used in this study.[14]

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[13] See Appendix Tables B.15 and 16 for details.

[14] Compared to the more detailed classification used in van Ark, Inklaar and McGuckin (2003b) parts of electrical machinery and instruments are now included as ICT producing, while computer services are excluded. We do not include wearing apparel and other transport equipment as ICT using industries, but we do include trade and repairs of motor vehicles and other business services as ICT using.

Table 2, Contributions to labour productivity growth in ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	2.30	1.21	-1.09	2.02	2.46	0.43	-0.27	1.25	1.52
ICT producing	0.44	0.51	0.06	0.65	0.89	0.24	0.21	0.38	0.18
ICT using	0.62	0.36	-0.26	0.59	1.43	0.84	-0.04	1.06	1.10
Non-ICT	1.21	0.48	-0.73	0.83	0.23	-0.60	-0.39	-0.25	0.14
Reallocation of hours	0.02	-0.15	-0.16	-0.04	-0.09	-0.05	-0.06	0.05	0.11

Notes: An industry's contribution is calculated as industry labour productivity growth weighted by the industry's value added share. The sum of the weighted industry growth rates does not sum to aggregate growth due to a reallocation effect shown in the bottom line of the table. This reallocation effect is positive if industries with high labour productivity levels have expanding employment. O'Mahony and van Ark (2003) and van Ark *et al.* (2003b) provide labour productivity growth analysis using a more refined classification of ICT producing and ICT using industries.

Source: see Appendix A

Table 3, Contributions to ICT capital deepening of ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	US	US-EU	EU-4	US	US-EU	EU-4	US	US-EU
Total economy	13.92	14.65	0.73	16.08	16.57	0.49	2.16	1.92	-0.24
ICT producing	1.70	2.06	0.36	2.03	2.04	0.01	0.33	-0.01	-0.35
ICT using	8.75	9.06	0.31	10.69	10.99	0.30	1.94	1.93	-0.01
Non-ICT	3.47	3.53	0.06	3.36	3.54	0.17	-0.11	0.00	0.11

Notes: An industry's contribution is calculated as industry ICT capital deepening weighted by the share of the industry's ICT capital compensation in aggregate ICT capital compensation.

Source: see Appendix A

In Table 2, aggregate labour productivity is decomposed into contributions from ICT producing, ICT using and non-ICT industries and a reallocation effect according to equation (16) in Section 2. In both the EU-4 and the U.S., the ICT producing sector accounts for around seven percent of GDP, but it accounts for about one third of labour productivity growth. The main differences between the EU-4 and the U.S. appear in the ICT using sector, which makes up around 30-35 percent of GDP. In the U.S., labour productivity growth in this sector contributed 1.06-percentage point to the aggregate labour productivity growth acceleration, but its contribution in EU-4 did not increase.

Although for the EU-4 as a whole labour productivity growth contribution in this sector has been flat, its contribution in the Netherlands and, more strongly, in the U.K. has increased, while it decreased in Germany, and especially in France. Full series showing the industry contributions to aggregate labour productivity growth by country are given in Appendix Tables B.1 and B.2.

4. ICT capital services growth

As shown above, the key to understanding the acceleration in U.S. labour productivity growth and the lack of it in the EU-4 is the difference in performance of industries that intensively use ICT and those that do not. This naturally raises the question whether this is due to lagging ICT investment in Europe, especially in ICT intensive industries. By weighting ICT capital deepening in each industry by its share in aggregate ICT capital compensation, industry contributions can be calculated. In Table 3 we show how much ICT producing, ICT using and non-ICT industries have contributed (in percentage points) to aggregate ICT capital deepening (growth in ICT capital services per hour worked). It is striking to see that the EU-4 and U.S. do not differ by much: ICT capital deepening has been progressing at double-digit growth rates since 1979 in both regions. Although growth has been faster in the U.S., the differences are relatively minor. This picture extends quite well to each of the industry groups. In both the EU-4 and the U.S. and in both periods, ICT using industries account for around two-thirds of aggregate ICT capital deepening, which is hardly surprising given the way the groups are defined. More notable is that ICT using industries make nearly identical contributions to the acceleration in ICT capital deepening in the EU-4 and the U.S. respectively. See tables B.11 and 12 for full industry and country detail.

The fact that ICT capital service growth is roughly similar in the EU and the U.S. does not contradict our earlier finding in Table 1 that ICT capital deepening makes a much larger contribution to aggregate labour productivity growth in the U.S. than the EU-4. This is due to the fact that ICT capital compensation makes up a much larger share of value added in the United States than in the EU-4 as shown in Table 4. This mirrors the finding of others (Colecchia and Schreyer, 2001; Oulton, 2001; Timmer, Ypma and van Ark 2003). The higher share is due to the fact that the *levels* of ICT-investment in the EU have always been much lower than in the U.S., although *growth rates* are comparable. Consequently, the absolute gap in ICT-capital intensity is increasing steadily. Table 4 shows that this is true for all industry groups.

Table 4, Average share of ICT capital in value added in ICT producing, ICT using and non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	2.49	3.37	0.87	3.28	5.22	1.93	0.79	1.85	1.06
ICT producing	6.18	13.21	7.03	8.40	15.59	7.19	2.22	2.38	0.16
ICT using	4.61	4.95	0.34	5.75	7.64	1.89	1.14	2.69	1.55
Non-ICT	0.99	1.34	0.35	1.20	2.26	1.06	0.21	0.92	0.71

Notes: The share of ICT capital in value added is calculated as the sum of capital compensation for computers, telecommunication equipment and software, divided by the industry's value added.

Source: see Appendix A

Table 5, Contributions to labour productivity growth of ICT capital deepening by ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.33	0.46	0.12	0.53	0.86	0.33	0.19	0.40	0.21
ICT producing	0.04	0.06	0.02	0.07	0.11	0.04	0.03	0.04	0.02
ICT using	0.21	0.28	0.07	0.35	0.57	0.22	0.14	0.29	0.15
Non-ICT	0.08	0.11	0.03	0.11	0.18	0.07	0.03	0.07	0.04

Notes: An industry's contribution is calculated as industry ICT capital deepening weighted by the share of the industry's ICT capital compensation in aggregate value added.

Source: see Appendix A

Table 6, Contributions to labour productivity growth of ICT capital deepening by ICT producing, ICT using and non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.33	0.46	0.12	0.53	0.86	0.33	0.19	0.40	0.21
ICT producing industries	0.04	0.06	0.02	0.07	0.11	0.04	0.03	0.04	0.02
Electrical and electronic equipment & instruments	0.01	0.04	0.02	0.02	0.05	0.04	0.00	0.02	0.01
Communications	0.03	0.02	0.00	0.05	0.05	0.00	0.02	0.03	0.01
ICT using industries	0.21	0.28	0.07	0.35	0.57	0.22	0.14	0.29	0.15
ICT using manufacturing	0.02	0.02	0.01	0.03	0.03	0.01	0.01	0.01	0.00
Wholesale trade	0.03	0.08	0.05	0.07	0.13	0.06	0.05	0.05	0.01
Retail trade	0.01	0.04	0.03	0.03	0.05	0.02	0.01	0.01	0.00
Financial intermediation	0.08	0.11	0.03	0.10	0.27	0.17	0.02	0.17	0.15
Business services	0.07	0.04	-0.03	0.12	0.09	-0.04	0.05	0.05	0.00
Non-ICT industries	0.08	0.11	0.03	0.11	0.18	0.07	0.03	0.07	0.04
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.00	0.01	0.01	0.00	0.00	0.00	0.00	-0.01	0.00
Non-ICT manufacturing	0.04	0.04	0.00	0.04	0.05	0.01	0.00	0.01	0.02
Transport & storage	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.00
Social and personal services	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.02	0.01
Non-market services	0.01	0.03	0.01	0.02	0.04	0.03	0.00	0.02	0.01
Other non-ICT	0.02	0.02	0.00	0.03	0.03	0.00	0.01	0.01	0.00

Note: See notes Table 5 for the calculation of the contributions. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT incudes utilities, construction and hotels & restaurants.

Source: see Appendix A

Between 1979 and 1995, ICT capital made up only 2.5 percent of aggregate value added in the EU-4 but 3.4 percent in the United States. For the 1995-2000 period, the gap had grown to nearly two percentage points. This gap can be found in all of the industry groups and is biggest in ICT producing industries. When comparing the two periods, the ICT share in the ICT using industries stands out as having grown much more in the U.S. than in EU-4. Between 1979 and 1995, the ICT share in value added was relatively close, but by 2000, the gap had grown to the point where ICT capital made up more than 7.5 percent of value added in U.S. ICT using industries, while it remained below six percent in the EU-4. The main reason for this is the small ICT capital stock in France, where at the aggregate level ICT capital makes up less than two percent of value added. The U.K. is at the other end of the spectrum with an aggregate ICT share of more than four percent and a share of more than seven percent in ICT using industries. Nevertheless the U.S. is still clearly ahead of all four European countries (see Appendix Tables B.15 and 16).

When combining ICT capital deepening in industry groups from Table 3 with the shares in Table 4 as in equation (20), one arrives at the contribution of ICT capital deepening in each industry to aggregate labour productivity growth. The results are shown in Table 5. The first row shows the contribution to aggregate labour productivity growth by ICT capital deepening in all industries. It corresponds to the row "contribution from ICT capital deepening" in Table 1. Subsequent rows decompose the contributions given in the first row by industry group. So for example the entry 0.35 for ICT using in EU-4 during 1995-2000 indicates that ICT-capital deepening in the ICT-using industries in the EU-4 contributed 0.35 percentage points to aggregate labour productivity growth in this period. In contrast, ICT capital deepening in ICT producing industries only contributed 0.07 percentage points.

This table makes clear that ICT using industries are responsible for the largest part of the difference in the aggregate contribution of ICT capital to labour productivity growth between the EU-4 and the United States (0.22 percentage points out of 0.33 percentage points). It is also the industry group where the difference has grown most in the late 1990s (0.15 percentage points).

To get a sharper picture of the acceleration in the contribution of ICT deepening, we look at the contribution of individual industries in Table 6. This table shows how only a few industries are responsible for the acceleration. In the U.S., nearly half of the aggregate acceleration can be traced to financial intermediation (0.17 percentage points out of 0.40). Together with wholesale trade and business services, this rises to 0.27 percentage points. In the EU-4 these same industries are also responsible for most of the acceleration, but in absolute terms both the contributions and the acceleration are much smaller than in the United States. The exception among the EU-4 countries is the U.K., where ICT capital deepening in wholesale trade actually made a larger contribution to aggregate labour productivity growth than in the U.S. Appendix Figure B.3 shows a ranking of contributions for all industries for 1995-2000 period, while Tables B.5 and B.6 provide full country and industry detail.

Outside the ICT using industries, the contributions are much lower. In the case of ICT producing industries this is mostly related to their smaller size. In non-ICT industries, however, it is clear that the low level of ICT investment diminishes their contributions. In this industry group only non-ICT manufacturing and non-market services make a sizeable contribution.

5. TFP growth

Although the differences in ICT investment are quite important for explaining the aggregate labour productivity growth differential, TFP growth also has a substantial role to play as was shown in Table 1. While aggregate TFP growth in the EU-4 increased only slightly after 1995, U.S. growth accelerated strongly. Which industries were responsible for this acceleration? The contribution to aggregate labour productivity growth, and hence to aggregate TFP growth, can be calculated as the growth of TFP in industry *i* weighted by the share of industry *i* in aggregate value added (see equation 23). The results are given in Table 7 and should be interpreted analogously to the results in Table 5. The first row shows the contribution to aggregate labour productivity growth by industry TFP growth, aggregated over all industries. It corresponds to the row "contribution from TFP" in Table 1. Subsequent rows decompose the contributions given in the first row by industry group. For example the value of 0.71 for ICT producing in the U.S. during 1995-2000 indicates that TFP growth in the ICT producing industries contributed 0.71 percentage points to aggregate labour productivity growth in the U.S.

The results in Table 7 show that in the EU-4 only TFP growth in the ICT producing industries showed a pronounced acceleration. In contrast TFP growth in ICT using industries stayed flat and growth even decelerated in non-ICT industries. Here it is important to note that although the contribution of ICT using industries in the EU-4 stayed flat, this is the product of a deceleration (from a high level) in France and an acceleration (from a negative contribution) in the U.K. (see Appendix Tables B.9 and B.10 for details).

The results for the U.S. show that the TFP growth acceleration mostly stems from ICT using industries, in addition to accelerating TFP growth in ICT-producing industries. After 1995, ICT producing industries still make the largest contribution to overall TFP growth, but the contribution of ICT using industries is almost as large. This confirms the findings of Jorgenson, Ho and Stiroh (2002) and Bosworth and Triplett (2003).[15] During the period 1995-2000, TFP growth in both sectors contributed about 0.70 percentage points to aggregate labour productivity growth, compared to 0.53 percentage points from ICT producing and a meagre 0.19 percentage points from ICT using in the EU-4. In fact the only reason that aggregate TFP in the EU-4 is still on par with the U.S. is due to the much higher contribution from TFP growth in non-ICT industries. During the 1995-2000 period it added 0.35 percentage points to aggregate labour productivity growth in the EU-4, but it contributed negatively in the U.S.

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[15] Due to the differences in the datasets used, Jorgenson, Ho and Stiroh (2003) and Bosworth and Triplett (2003) disagree about the relative importance of TFP growth acceleration in ICT-goods manufacturing versus ICT-using industries (compare the results of Jorgenson, Ho and Stiroh presented their Figure 26 and those of Bosworth and Triplett in their Table 6). In the latter study the contribution of services to TFP acceleration is much bigger than in the former study. See Bosworth and Triplett (2003) for a discussion of possible causes of these differences.

Table 7, Contributions to total factor productivity growth in ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	US-EU	EU-4	U.S.	US-EU	EU-4	U.S.	US-EU
Total economy	0.94	0.26	-0.67	1.07	1.05	-0.02	0.13	0.79	0.66
ICT producing	0.30	0.35	0.06	0.53	0.71	0.18	0.24	0.36	0.12
ICT using	0.17	-0.15	-0.31	0.19	0.68	0.50	0.02	0.83	0.81
Non-ICT	0.48	0.06	-0.42	0.35	-0.34	-0.69	-0.13	-0.40	-0.27

Notes: An industry's contribution is calculated as industry total factor productivity growth weighted by the industry's value added share.

Source: see Appendix A

Table 8, Contributions to total factor productivity growth of ICT producing and ICT using industries and non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.94	0.26	-0.67	1.07	1.05	-0.02	0.13	0.79	0.66
ICT producing industries	0.30	0.35	0.06	0.53	0.71	0.18	0.24	0.36	0.12
Electrical and electronic equipment & instruments	0.21	0.36	0.15	0.27	0.63	0.35	0.07	0.27	0.20
Communications	0.09	-0.01	-0.10	0.26	0.08	-0.18	0.17	0.09	-0.08
ICT using industries	0.17	-0.15	-0.31	0.19	0.68	0.50	0.02	0.83	0.81
ICT using manufacturing	0.03	-0.07	-0.11	0.03	-0.01	-0.05	0.00	0.06	0.06
Wholesale trade	0.11	0.04	-0.07	0.08	0.35	0.27	-0.02	0.31	0.34
Retail trade	0.06	0.10	0.05	0.03	0.39	0.36	-0.03	0.28	0.31
Financial intermediation	0.00	-0.19	-0.19	0.06	0.08	0.02	0.06	0.27	0.22
Business services	-0.03	-0.02	0.01	-0.02	-0.12	-0.11	0.01	-0.10	-0.11
Non-ICT industries	0.48	0.06	-0.42	0.35	-0.34	-0.69	-0.13	-0.40	-0.27
Agriculture, forestry and fishing	0.09	0.13	0.04	0.06	0.16	0.10	-0.03	0.03	0.06
Mining and quarrying	-0.01	0.00	0.01	0.01	-0.02	-0.04	0.02	-0.02	-0.05
Non-ICT manufacturing	0.21	0.17	-0.04	0.08	-0.07	-0.15	-0.14	-0.25	-0.11
Transport & storage	0.09	0.05	-0.04	0.13	0.05	-0.08	0.04	0.00	-0.04
Social and personal services	-0.02	0.00	0.02	-0.02	-0.11	-0.09	0.01	-0.10	-0.11
Non-market services	0.07	-0.24	-0.31	0.07	-0.30	-0.37	0.00	-0.06	-0.06
Other non-ICT	0.04	-0.05	-0.09	0.02	-0.05	-0.07	-0.03	0.00	0.03

Note: See notes Table 7 for the calculation of the contributions. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT incudes utilities, construction and hotels & restaurants.

Source: see Appendix A

Table 8 shows the contribution to TFP growth of some of the individual industries. ICT producing industries make the largest contribution to TFP growth in both the EU-4 and U.S. In the U.S. most of the contribution can be traced to ICT producing manufacturing while in the EU-4 communications services play a much more important role.

The acceleration in the TFP contribution of ICT using industries in the U.S. is mostly related to accelerations in three industries: wholesale trade, retail trade and financial intermediation. In contrast, in the EU-4 none of these industries is an important contributor to aggregate TFP growth. In fact contributions from the trade industries even declined. While this holds for all EU-4 countries in the case of retail trade, the TFP contribution of wholesale trade in the U.K. is relatively high, while in the Netherlands the absolute contribution is even higher than in the U.S. In financial intermediation, Germany and the U.K. also had higher contributions to TFP growth than the U.S., but this was cancelled out by negative contributions in France and the Netherlands. Appendix Tables B.9 and B.10 provide full country and industry detail.

TFP growth has not been confined to ICT producing and ICT using industries. A striking finding in Table 7 was the dependence of aggregate TFP growth in EU-4 on non-ICT industries. Table 8 shows that this mainly involved contributions from transport and storage, non-market services and other non-ICT industries. In contrast, in the U.S. the contributions from these sectors were small or even negative. Only the contribution of agriculture was higher in the U.S. than in the EU-4. In fact agriculture in the U.S. made one of the largest contributions to aggregate labour productivity growth in both periods (see Appendix Figure B.5). There was a deceleration in the contribution of non-ICT industries to TFP growth after 1995 in both regions, which is mostly related to a strong decline in the contribution of non-ICT manufacturing.

Some studies have raised the possibility that externalities (be it production spillovers or network effects) would drive higher productivity growth in ICT-using industries compared to non-ICT industries. This is clearly true for labour productivity growth as rapid ICT investment directly enhances labour productivity growth through its capital deepening effect. However, the effects on TFP growth are less evident. If ICT investment earns a normal rate of return and there are no substantial externalities associated with ICT, no association between TFP and ICT capital intensification is to be expected.[16] For the U.S. Bosworth and Triplett (2003) did not find a correlation between the two, confirming the analysis for the U.S. by Stiroh (2002a). Appendix Figures B.3 and B.5 confirm the findings from these studies: U.S. wholesale trade and financial intermediation rank near the top of the industry list in terms of both contributions from TFP growth and ICT capital deepening. The contribution of retail trade to aggregate labour productivity growth has been more modest but it made the second-largest contribution to overall TFP growth in the U.S. Business services on the other hand made a very sizeable contribution to ICT capital deepening in both the EU-4 and U.S. but showed negative TFP growth throughout the period in both.[17]

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[16] See Bosworth and Triplett (2003, p.23).

[17] Here it should be noted that business services is one of the industries where real output is hardest to measure, so an understatement of TFP growth cannot be ruled out. Similar arguments can be made in the case of financial intermediation and non-market services. See for example Eurostat (2001) for a discussion of measurement problems in these and other industries.

6. Labour quality growth

Differences in labour quality growth are relatively unimportant in terms of explaining the aggregate labour productivity growth differential between the EU-4 and the U.S. However, the results at the industry level do point to some noticeable differences between the two regions. The contribution to aggregate labour productivity growth can be calculated as the growth of labour quality in industry *i* weighted by the share of labour compensation in industry *i* in aggregate nominal value added (see equation 22). The results are given in Table 9 and should be interpreted analogously to the results in Table 5 and 7. The first row shows the contribution to aggregate labour productivity growth by labour quality change in all industries. It corresponds to the row "contribution from labour quality" in Table 1. Subsequent rows decompose the contributions given in the first row by industry group.

Table 9 shows that after 1995 the contribution of labour quality growth to aggregate labour productivity growth slowed down in both the EU-4 and the U.S. Throughout the period the EU-4 had a somewhat higher contribution, but the contributions were generally close. Here it should be remarked that the main source of EU-4 labour quality growth stems from the U.K., which showed considerably higher contributions in both periods than the other European countries. However, the pattern across industries is quite similar to the EU-4 total (see Appendix Tables B.3 and B.4).

Bigger differences can be seen when looking at the ICT producing, ICT using and non-ICT industries. Between 1979 and 1995, the labour quality contribution from non-ICT industries was much larger in the EU-4, while the contribution from ICT using industries was bigger in the U.S. After 1995 these differences mostly disappeared.

Table 10 shows the contribution to aggregate labour productivity growth of labour quality growth in individual industries. This table shows that between 1979 and 1995, non-ICT manufacturing in the EU-4 shows particularly large contributions. Together with the larger contribution from non-market services, these larger contributions more than account for the aggregate differential. After 1995 the differential in these industries between the EU-4 and U.S. mostly disappeared, but especially non-ICT manufacturing still showed somewhat larger contributions in the EU-4 than the U.S.

In the U.S. on the other hand, the labour quality contribution of finance and business services was noticeably higher than in the EU-4. In business services, this position was reversed after 1995 with the EU-4 showing a larger contribution. This suggests that the expansion in employment in this sector is not only due to an expansion in low-skilled jobs such as cleaners or security personnel. Furthermore, the earlier lead of the U.S. in these ICT using services points to possible ICT-skill complementarities. Still, these findings should not be carried too far since the contributions to aggregate labour productivity growth are small relative to contributions from other sources.

Table 9, Contributions to labour productivity growth of labour quality growth in ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.31	0.28	-0.03	0.22	0.22	-0.01	-0.09	-0.07	0.02
ICT producing	0.03	0.04	0.01	0.02	0.01	-0.01	-0.01	-0.02	-0.02
ICT using	0.07	0.10	0.03	0.08	0.07	-0.01	0.01	-0.03	-0.04
Non-ICT	0.21	0.14	-0.07	0.12	0.13	0.01	-0.09	-0.01	0.08

Notes: An industry's contribution is calculated as industry labour quality growth weighted by the share of the industry's labour compensation in aggregate value added.

Source: see Appendix A

Table 10, Contributions to labour productivity growth of labour quality growth by ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.31	0.28	-0.03	0.22	0.22	-0.01	-0.09	-0.07	0.02
ICT producing industries	0.03	0.04	0.01	0.02	0.01	-0.01	-0.01	-0.02	-0.02
Electrical and electronic equipment & instruments	0.02	0.03	0.01	0.01	0.01	0.00	-0.01	-0.02	-0.01
Communications	0.01	0.01	0.00	0.01	0.01	-0.01	0.01	0.00	-0.01
ICT using industries	0.07	0.10	0.03	0.08	0.07	-0.01	0.01	-0.03	-0.04
ICT using manufacturing	0.02	0.02	-0.01	0.01	0.01	0.00	-0.01	-0.01	0.01
Wholesale trade	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Retail trade	0.01	0.01	0.00	0.01	0.01	0.00	-0.01	0.00	0.00
Financial intermediation	0.01	0.03	0.02	0.01	0.01	0.00	0.00	-0.01	-0.02
Business services	0.01	0.03	0.02	0.04	0.03	-0.01	0.02	0.00	-0.03
Non-ICT industries	0.21	0.14	-0.07	0.12	0.13	0.01	-0.09	-0.01	0.08
Agriculture, forestry and fishing	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-ICT manufacturing	0.07	0.04	-0.03	0.03	0.02	-0.01	-0.04	-0.02	0.02
Transport & storage	0.02	0.01	-0.01	0.00	0.01	0.01	-0.02	0.00	0.02
Social and personal services	0.01	0.02	0.01	0.01	0.01	0.00	0.00	-0.01	-0.01
Non-market services	0.08	0.06	-0.02	0.06	0.08	0.01	-0.01	0.02	0.03
Other non-ICT	0.03	0.01	-0.02	0.01	0.01	0.00	-0.01	0.00	0.02

Note: See notes Table 9 for the calculation of the contributions. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing. Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment. Other non-ICT incudes utilities, construction and hotels & restaurants.

Source: see Appendix A

7. Non-ICT capital service growth

Differences in ICT capital deepening and TFP growth by industry appeared to be important in explaining the aggregate labour productivity divergence between the EU-4 and the U.S. They explain well why Europe is lagging behind the U.S. in the period 1995-2000, but they do not explain why Europe's labour productivity growth slowed down so much compared to the previous period. As discussed in the previous section, this deceleration also cannot be explained by trends in labour quality growth. Therefore we now turn to investment trends in non-ICT assets. As Table 1 showed, EU-4 non-ICT capital deepening decelerated sharply after 1995. Due to the relatively large share of non-ICT capital in total capital this is a major factor in explaining the deceleration of labour productivity growth.

The contribution of non-ICT capital deepening in industry i to aggregate labour productivity growth can be calculated as the growth of non-ICT capital per hour worked in industry i weighted by the share of capital compensation in industry i in aggregate nominal value added (see equation 21). The results are given in Table 11 and should be interpreted analogously to the results in Table 5, 7 and 9. The first row shows the contribution to aggregate labour productivity growth by non-ICT capital deepening in all industries. It corresponds to the row "contribution from non-ICT capital deepening" in Table 1. Subsequent rows decompose the contributions given in the first row by industry group.

The striking finding in Table 11 is that the deceleration in the EU-4 has been very widespread, with all industry groups showing declines in non-ICT capital deepening contributions. In fact almost all industries show decelerations after 1995. The only exception is in the other non-ICT industries group, with most of this acceleration stemming from utilities. Although the deceleration of non-ICT capital deepening in the EU-4 is widespread, a number of industries stand out. First of all, total manufacturing (ICT producing, ICT using and non-ICT manufacturing) is responsible for around one-third of the aggregate deceleration, which is much bigger than its share in GDP. More than a quarter of the aggregate deceleration can be traced to business services where non-ICT capital per hour worked was actually declining after 1995. Finally, mining makes up another 20 percent of the deceleration. This industry showed a similar contribution decline in the U.S. It is furthermore remarkable that these developments can be seen, to a greater or lesser extent, in all four European countries (see Appendix Tables B.7, B.8, B.13 and B.14).

In focusing on the slowdown in non-ICT capital deepening in the EU-4 we should not lose sight of the fact that before 1995, non-ICT capital deepening progressed at a much faster pace than in the U.S. in almost all industries, except some ICT-using industries. After 1995 the contributions in the EU-4 and U.S. from especially the non-ICT industries are more similar. One interpretation of the declines after 1995 is that the possibilities for European catch-up were mostly exhausted by 1995 and that growth slowed down to a pace more comparable to the productivity leader. To investigate this hypothesis, relative levels of output and inputs would be required though. Another explanation would be that movements in factor prices play an important role.

Table 11, Contributions to labour productivity growth of Non-ICT capital deepening by ICT producing, ICT using and Non-ICT industries, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Total economy	0.70	0.35	-0.35	0.25	0.43	0.18	-0.45	0.08	0.53
ICT producing industries	0.08	0.05	-0.02	0.03	0.06	0.04	-0.05	0.01	0.06
Electrical and electronic equipment & instruments	0.04	0.04	0.00	0.01	0.04	0.03	-0.03	0.01	0.04
Communications	0.04	0.02	-0.02	0.02	0.02	0.00	-0.02	0.00	0.02
ICT using industries	0.18	0.12	-0.05	-0.03	0.10	0.13	-0.20	-0.02	0.18
ICT using manufacturing	0.05	0.01	-0.04	0.02	0.01	-0.01	-0.03	0.00	0.03
Wholesale trade	0.02	0.04	0.02	0.01	0.03	0.02	-0.02	-0.01	0.01
Retail trade	0.02	0.04	0.02	0.01	0.04	0.03	-0.01	0.00	0.01
Financial intermediation	0.03	0.08	0.05	0.00	0.08	0.08	-0.03	0.01	0.03
Business services	0.05	-0.04	-0.10	-0.07	-0.06	0.01	-0.12	-0.02	0.10
Non-ICT industries	0.44	0.17	-0.27	0.25	0.26	0.02	-0.20	0.09	0.29
Agriculture, forestry and fishing	0.03	0.00	-0.04	0.03	0.02	0.00	-0.01	0.03	0.03
Mining and quarrying	0.13	0.10	-0.03	0.04	0.02	-0.01	-0.09	-0.07	0.02
Non-ICT manufacturing	0.14	0.06	-0.08	0.06	0.08	0.02	-0.08	0.02	0.10
Transport & storage	0.01	-0.02	-0.03	0.00	0.01	0.01	-0.01	0.03	0.04
Social and personal services	0.02	0.01	-0.02	-0.01	0.02	0.03	-0.04	0.01	0.05
Non-market services	0.04	0.03	-0.01	0.03	0.04	0.01	0.00	0.01	0.02
Other non-ICT	0.07	0.01	-0.06	0.10	0.07	-0.03	0.03	0.06	0.03

Notes: An industry's contribution is calculated as industry non-ICT capital deepening weighted by the industry's share of non-ICT capital compensation in aggregate value added. ICT using manufacturing includes paper, printing & publishing, machinery and furniture and miscellaneous manufacturing
Non-ICT manufacturing includes food, textiles, wood, petroleum, chemicals, rubber & plastics, non-metallic mineral, metal products and transport equipment
Other non-ICT incudes utilities, construction and hotels & restaurants
Source: see Appendix A

Table 12, Growth in wage/rental ratios and in non-ICT and ICT capital per hour worked, EU-4 and U.S.

	1979-1995			1995-2000			Change 1995-2000 over 1979-1995		
	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU	EU-4	U.S.	U.S.-EU
Nominal wage growth	5.97	5.06	-0.90	2.91	3.97	1.06	-3.05	-1.09	1.96
Non-ICT rental rate growth	4.09	3.79	-0.30	2.39	2.51	0.12	-1.70	-1.28	0.42
ICT rental rate growth	-6.21	-5.16	1.04	-12.46	-10.10	2.36	-6.25	-4.94	1.32
Wage/non-ICT rental rate	1.88	1.27	-0.61	0.53	1.46	0.94	-1.35	0.19	1.54
Wage/ICT rental rate	12.18	10.23	-1.95	15.37	14.07	-1.30	3.20	3.84	0.65
Non-ICT capital deepening	2.59	1.46	-1.14	0.88	1.79	0.91	-1.71	0.33	2.04
ICT capital deepening	13.92	14.65	0.73	16.08	16.57	0.49	2.16	1.92	-0.24

Source: see Appendix A

8. Factor prices and capital deepening

The strong deceleration in non-ICT capital deepening in the EU-4 in the late 1990s has coincided with a sharp rise in employment (see for example van Ark, Inklaar, McGuckin and Timmer 2003a). In the standard neo-classical framework we have been employing in this paper, movements in relative prices are the foremost candidates for explaining such a development. In Table 12 we show the growth in nominal wages, rental rates and wage-rental ratios for non-ICT and ICT capital. Wage growth is defined as the growth in labour compensation per hour worked, where both labour compensation and hours worked are summed across industries. Hours worked are not adjusted for labour quality change, but the results are qualitatively similar if labour quality change is taken into account. Rental prices are defined in equation (2) in Section 2 and aggregate rental prices are calculated as industry weighted averages. The first three rows give the annual average growth rates of nominal wages, non-ICT and ICT rental prices. Row four and five indicate the development of wage-rental ratios for each capital based on the previous rows. The last rows indicate trends in capital deepening underlying Table 1.

The results of table 12 are quite suggestive. As we have seen before, ICT capital per hour worked has been rising rapidly throughout the 1979-2000 period. In both the EU-4 and the U.S., wage/ICT rental ratios increased as ICT rental prices decreased more rapidly than wages. Furthermore, the acceleration in ICT capital deepening given in the last columns of Table 12 can be traced to a more rapid decline in ICT rental rates as suggested by Jorgenson (2001).

Similarly, developments in the wage/non-ICT rental ratio are mirrored in non-ICT capital deepening. Most interestingly, the strong deceleration in the growth of wages relative to non-ICT rental rates after 1995 in the EU-4, in contrast to the U.S., suggests that relative factor price movements potentially play an important role in explaining the slowdown in non-ICT capital deepening in the EU-4, a development that did not take place in the U.S. To more formally address this problem we specify an econometric model to explain capital deepening by movements in factor prices:

$$\Delta\left(k^{I}_{i,t} \big/ l_{i,t} \right) = \beta_1 \Delta w_{i,t} + \beta_2 \Delta r^{I}_{i,t} + \eta_i + \nu_t + \varepsilon_{it} \tag{24}$$

The dependent variable in equation (22) is the growth in ICT capital services per hour worked (indicated by the superscript *I*) in industry *i* at time *t*. As the independent variable we use the growth in wages (denoted by w) relative to the ICT rental rate (denoted by r^I). Since we have a panel of data, the error term is split into an industry fixed effect, η_i, a time effect ν_t and ε_{it}, in which the interaction of errors in the time and industry dimension are combined. We take out the industry effect by calculating the fixed effects estimator.[18] Year dummies are included to remove the time effect. We estimate this equation with both ICT and non-ICT

[18] There is no constant term in this specification since the fixed effects take account of industry-specific intercepts.

capital deepening as the dependent variable. For the regressions with non-ICT capital deepening as the dependent variable we use the growth in non-ICT rental rates instead of ICT rental rates as one of the independent variables.

For our growth accounts we have been assuming perfect competition, which allows us to equate marginal cost of inputs with marginal productivity. Under this assumption all firms are price takers on the market for factor inputs, which means that input prices can be regarded as exogenous variables in our regression model. We also assume that changes in factor prices are contemporaneously related to capital deepening so that no lagged terms enter the equations. This decision was based on autocorrelation matrices, which show that the largest correlation between the wage/rental ratios and capital deepening occurs contemporaneously. Under the assumption of perfect competition and using only contemporaneous variables, equation (22) can be estimated using ordinary least squares (OLS).

In Table 13 we present results for regressions based on equation (24). In our estimates for non-ICT capital deepening (panel A) we exclude structures.[19] We exclude the mining and petroleum industries from our dataset because of their volatile behaviour, leaving us with 24 industries and 2520 observations overall.[20] In the table we present country-specific parameters because the hypothesis of identical coefficients across countries is overwhelmingly rejected by the data. Country groupings such as the EU-4 or Anglo-Saxon countries (U.K., U.S.) versus 'Rhineland' countries (France, Germany, Netherlands) are also not supported by the data.

As the table shows, wage growth is an important determinant of non-ICT capital deepening. In all countries the coefficient on wage growth is highly significant and positive, as faster wage growth can be expected to lead to substitution of non-ICT capital for labour. However, non-ICT rental rates only have a significant negative impact on non-ICT capital deepening in the case of Germany and the U.S., with insignificant coefficients for the other countries. When comparing the EU with the U.S., the differences in parameters stand out. In the U.S. capital intensity is much more sensitive to price changes as shown in the larger estimates for the effects of wages and capital prices. This is indicative of the difference in organisation of factor input markets, especially labour markets in (Continental) Europe versus the U.S. Overall, the regressions for non-ICT capital do suggest that the wage moderation in

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[19] We also experimented with using the wage-rental ratio instead of the factor prices separately. This alternative (where we in effect impose $\beta_1 = -\beta_2$) is firmly rejected by the data. We also tried including the rental price of the other asset, so for example estimating the effect of changes in the non-ICT rental rate on ICT capital deepening. However, these parameters were not significant in most of the countries. The reason for excluding structures is that substitution of buildings for hours worked (or vice versa) is probably a more protracted process than we are able to model given our time series. However, most significant parameters remain significant if structures were included, only the coefficients on wage growth decrease. Furthermore, aggregate non-ICT capital deepening excluding structures in the EU-4 shows a similar deceleration as non-ICT capital deepening including structures. Results are available from the authors on request.

[20] The main difference compared to estimates for the full set industries is that many of the variables are more significant than if the two outliers are included in the estimation. We also estimated our regressions using weighted least squares with total hours worked as weights. Results are comparable in most cases and the impact of removing mining and petroleum decreases. However, this procedure puts a large weight on non-market services (around 25 percent). The main justification for using the size of the industry as a weight is that in larger sector s measurement errors are more likely to cancel out (see e.g. Stiroh, 2002a). While this may well hold for manufacturing industries, it is less plausible for service industries so we only report OLS results. WLS results are available from the authors on request.

the EU-4 as shown in Table 12 has played an important role in the slowdown in non-ICT capital deepening.

The results for the regressions with ICT capital deepening as the dependent variable are more mixed. In the Netherlands, U.K. and U.S., the coefficient on wage growth is significant and positive. For France and Germany, though, the coefficient is negative, implying that faster wage growth is related to faster ICT capital deepening. ICT rental rates only have a significant impact on ICT capital deepening in the U.S., but there the impact is positive, which is also hard to reconcile with economic theory.

These results suggest that to gain a better understanding of ICT investment behaviour, we need to look beyond the simple and fairly ad-hoc models we have estimated so far. One extension would be to look at the role of wage growth for different skill categories since ICT-skill complementarities might exist (see e.g. Chun, 2003 and O'Mahony *et al.*, 2003). ICT investment might also be influenced by other considerations such as the desire to make use of specific technical features of ICT technology, which are hard to generate with non-ICT capital or labour (for example Internet related features such as electronic shopping). Although these issues certainly deserve more attention, they fall outside the scope of this paper.

Table 13, Explaining ICT and non-ICT capital deepening by factor price changes, 1979-2000

A: Non-ICT capital deepening		France	Germany	Netherlands	UK	US	
Wage growth	β_1	0.302**	0.460**	0.550**	0.425**	0.582**	
		(9.961)	(5.032)	(6.068)	(9.411)	(8.159)	
Non-ICT rental rate growth	β_2	0.011	-0.081**	0.021	-0.008	-0.124**	
		(0.685)	(-0.081)	(0.648)	(-0.854)	(-5.636)	
Adjusted R-squared							0.202
B: ICT capital deepening							
Wage growth	β_1	-0.103**	-0.039**	1.036**	0.190**	0.736**	
		(-1.345)	(-0.319)	(6.797)	(2.017)	(4.415)	
ICT-rental rate growth	β_2	0.016	0.042	-0.068	-0.023	0.169*	
		(0.739)	(1.546)	(-1.421)	(-1.069)	(2.004)	
Adjusted R-squared							0.182

Dependent variable is the growth in non-ICT capital (excluding structures) per hour worked in panel A and ICT capital per hour worked in panel B. Wage is defined as labour compensation per hour worked in each industry, without labour quality adjustments. Estimates using OLS with fixed effects for each country-industry pair as well as year dummies. Standard errors are consistent for heteroscedasticity. t-statistics are displayed in parentheses below the parameter estimates.

*: significant at 5%, **: significant at 1% using two-tailed tests. Mining and petroleum industries have been excluded.

9. Comparisons with other industry studies

Industry level growth-accounting decompositions of aggregate labour productivity trends are still few. The main ones include Jorgenson, *et al.* (2002) and Bosworth and Triplett (2003) for the U.S., and Basu, Fernald, Oulton and Srinivasan (2003), which compare U.S. with the U.K. The findings for the U.S. in this paper are broadly consistent with the findings of the other studies. However, estimates sometimes differ greatly at the detailed industry level, for example about the relative importance of the TFP growth acceleration in ICT-goods manufacturing versus ICT-using industries. In Bosworth and Triplett (2003, Table 6) the contribution of services to TFP growth acceleration is much bigger than in Jorgenson, *et al.* (2002, Figure 26). And while Jorgenson *et al.* (2002) show an acceleration in TFP growth in retail trade and a deceleration in wholesale trade, Bosworth and Triplett (2003) find an acceleration in both. Our estimates, and those of Basu, Fernald, Oulton and Srinivasan (2003), are much closer to those of Bosworth and Triplett (2003) than to Jorgenson, *et al.* (2002).

The different findings are due to many differences both in data sources and methodology. We mention three important ones. First, our analysis is based on value added measures and therefore does not take into account the role of intermediate inputs as the U.S. studies do. This will affect TFP growth estimates, but much less so measures of TFP acceleration or deceleration, which are the main focus here. Second, the capital concept of Jorgenson, *et al.* (2002) is broader than in the other studies by including inventories, land and consumer durables. Third, the data used in this study is benchmarked on industry accounts from the BEA NIPA for output, labour input and investment flows. Bosworth and Triplett (2003) use a hybrid database by combining BEA industry accounts with capital service flows from the BLS.[21] Basu, Fernald, Oulton and Srinivasan (2003) use a similar database as Bosworth and Triplett (2003).[22] Jorgenson, *et al.* (2002) on the other hand combine BLS inter-industry accounts with investment flows from the BEA and they benchmark labour input on BEA NIPA hours. BLS and BEA datasets show important differences in some industries, even for relatively simple measures such as gross output and value added at current prices. Bosworth and Triplett (2003) provide a discussion of these differences and their possible origins but they conclude that many questions still remain.

For the U.K. Basu *et al.* (2003) use implicit measures of value added at constant prices using double-deflation. Double-deflation is not used consistently throughout the U.K. national accounts. Since we base our estimates of value added at constant prices on the U.K. national accounts, differences at the industry level can be substantial.[23] Another difference between the two datasets comes from the estimates for aggregate software investment. Both estimates scale up software from the national accounts as this is widely regarded as an underestimate, since it is not consistent with survey based evidence. But the adjustment in this paper is smaller. As a result, our estimates of the share of ICT capital in value added come out lower

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[21] In contrast to the other studies, they do not correct labour input for hours worked, nor for quality changes.

[22] Except for labour input where they use estimates of hours worked by industry from the BLS instead of persons engaged in production from the BEA.

[23] Compare Table 5 of Basu *et al.* with our Tables B.23 and B.24.

than the estimates of Basu *et al*[24].. Whereas both this paper and Basu *et al.* (2003) find TFP acceleration in finance and wholesale trade, this paper also finds a small increase in other ICT using sectors. Further research is needed to reconcile these findings, especially concerning the differences between single and double deflated value added.

10. Concluding remarks

This paper began by raising the question why U.S. productivity growth accelerated after 1995, while growth in four major EU countries (France, Germany, Netherlands and U.K.) decelerated. Much of the growth accounting literature in recent years has been dominated by trends in the U.S. and so has focused largely on the impact of ICT on output growth. This new technology focus has also dominated the analysis of productivity growth for other industrial countries. But by doing so there is a danger that research ignores the possibility that the stylised facts on output and productivity growth in other nations may be different from those in the U.S. Indeed, as was shown in earlier work that focused on aggregate trends, the sources of U.S. acceleration and EU slowdown are very different (see Timmer, Ypma and van Ark, 2003). In this paper we have sharpened this picture by analysing productivity growth at the industry-level. It appears that aggregate trends conceal much heterogeneity among the industries.

To understand the U.S. acceleration it is important to focus on services industries that use ICT intensively. These industries, mainly trade and finance, are responsible for most of the acceleration in ICT capital deepening and TFP growth alike. Together with faster technical progress in ICT producing industries, they explain most of the acceleration in U.S. labour productivity growth after 1995.

In contrast, in the EU-4 the contributions from ICT capital deepening and TFP growth are much lower than in the U.S. It is true that the same industries as in the U.S. make the largest contribution to ICT capital deepening, but the absolute contributions are much lower due to lower levels of ICT capital stocks. Furthermore, these intensive ICT users have not generated faster TFP growth. EU-4 TFP growth remained mostly confined to industries that produce ICT goods and services. This raises interesting questions on the extent to which these EU countries are merely lagging the U.S., given the latter country's faster adoption of ICT, or whether there are institutional constraints that prevent EU countries from realising the full benefits from ICT.

However, this paper has shown that ICT is not the dominant explanation of the slowdown in labour productivity growth, at least in the four large EU countries studied. To explain the slowdown in the European countries we need to look at non-ICT capital deepening, whose contribution slowed down in most of the EU-4 industries, with the largest declines occurring in manufacturing, business services and mining. One likely candidate for explaining such a development is slower (nominal) wage growth in the EU-4 as this may well have induced a substitution of labour for non-ICT capital. This finding suggests that more research using models that relate input substitution to factor prices is worthy of further study.

[24] Compare Table 7 of Basu *et al.* with our Table B.16.

This will need to be placed in the context of post-war catch up and overtaking of European countries relative to the U.S. in levels of capital per hour worked and any complementarities between capital and stocks of skilled labour.

There are also other important analytical issues that cannot be easily understood in a simple growth accounting framework. These include possible spillovers of ICT to TFP growth, complementarities between ICT and skills and the importance of investment in intangibles such as organizational capital.[25] So far the evidence available on these issues has focused almost solely on the U.S. However, the dataset used in this paper and the stylised facts that were presented should allow more and better research into these issues.

[25] See for example Stiroh (2002a) and O'Mahony and Vecchi (2003) for some evidence on the possibility of ICT spillovers, Chun (2003) and O'Mahony, Robinson and Vecchi (2003) for evidence on ICT-skill complementarities, Brynjolfsson and Hitt (2000) for the importance of organizational capital and Basu, Fernald, Oulton and Srinivasan (2003) for a discussion of complementary capital and consequences for lagged TFP responses.

References

Basu, Susanto, John G. Fernald and Matthew D. Shapiro, "Technology, Utilization, or Adjustment? Productivity Growth in the 1990s," forthcoming in Carnegie-Rochester Conference Series on Public Policy, 2002.

—, —, Nicholas Oulton and Sylaja Srinivasan, "The Case of the Missing Productivity Growth: Or, Does Information Technology Explain Why Productivity Accelerated in the United States but not in the United Kingdom?", forthcoming in Mark Gertler and Kenneth Rogoff (eds.), NBER Macroeconomics Annual, 2003.

Bosworth, Barry P. and Jack E. Triplett, "Baumol's Disease Has Been Cured: IT and Multifactor Productivity in U.S. Services Industries" forthcoming in Dennis W. Jansen (ed.), The New Economy. How New? How Resilient? University of Chicago Press, Chicago, 2002.

—, —, "Services Productivity in the United States: Griliches' Services Volume Revisited", downloadable at http://www.brookings.edu/views/papers/bosworth/20030919.htm, 2003.

Brynjolfsson, Erik and Lorin Hitt, "Beyond computation: information technology, organizational transformation and business performance", Journal of Economic Perspectives, vol. 14, no. 4, pp. 23-48, Fall 2000.

Chun, Hyunbae, "Information Technology and the Demand for Educated Workers: Disentangling the Impacts of Adoption versus Use", Review of Economics and Statistics, vol. 85, no. 1, pp. 1-8, February 2003.

— and Sung-Bae Mun, "Substitutability and Accumulation of Information Technology Capital in U.S. Industries", downloadable at http://www.qc.edu/~hchun/its20.pdf, July 2003.

Colecchia, Alessandra and Paul Schreyer, "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case?: A Comparative Study of Nine OECD Countries," Review of Economic Dynamics, vol. 5, pp. 408-442, 2002.

Daveri, Francesco, "Is growth an information technology story in Europe too?", IGIER working paper, no. 168, September 2000.

—, "The New Economy in Europe, 1992-2001,", Oxford Review of Economic Policy, vol. 18, pp. 345-362, 2002.

Doms, Mark, "Communications Equipment: What Has Happened to Prices?" Forthcoming in *Measuring Capital in the New Economy*, NBER/CRIW, University of Chicago Press, 2003.

Eurostat, Handbook on price and volume measures in national accounts, Eurostat, Luxembourg, 2001.

Fraumeni, Barbara M. (1997) "The Measurement of Depreciation in the U.S. National Income and Product Accounts", Survey of Current Business, July 1997.

Gordon, Robert J., "Does the 'New Economy' Measure up to the Great Inventions of the Past?", Journal of Economic Perspectives, vol. 14, no. 4, pp. 49-74, Fall 2000.

—, "Hi-Tech Innovation and Productivity Growth: Does Supply Create its Own Demand?" NBER Working Paper, no. 9437, January 2003.

Groningen Growth and Development Centre, 60-industry database, downloadable at www.ggdc.net, 2003.

Hulten, Charles R. "Total Factor Productivity: A Short Biography" in Charles R. Hulten, Edwin R. Dean and Michael J. Harper (eds.) New Developments in Productivity Analysis, University of Chicago Press, Chicago, 2001.

Inklaar, Robert, Mary O'Mahony, Catherine Robinson and Marcel P. Timmer, "Productivity and Competitiveness in the EU and the U.S.", in Mary O'Mahony and Bart van Ark (eds.) EU Productivity and Competitiveness: A Sectoral Perspective; Can Europe Resume the Catching-Up Process?, European Commission, Brussels, November 2003a.

—, Lucy Stokes, Edwin Stuivenwold, Marcel P. Timmer and Gerard Ypma, "Data Sources and Methodology", in Mary O'Mahony and Bart van Ark (eds.) EU Productivity and Competitiveness: A Sectoral Perspective; Can Europe Resume the Catching-Up Process?, European Commission, Brussels, November 2003b.

Jorgenson, Dale W. and Zvi Griliches, "The Explanation of Productivity Change", Review of Economic Studies, Vol. 34, pp. 249-83, 1967.

—, Frank M. Gollop and Barbara M. Fraumeni, Productivity and U.S. Economic Growth, Harvard University Press, Cambridge, 1987.

— "Information Technology and the U.S. Economy" American Economic Review, vol. 91 no. 1, pp. 1-32, March 2001.

— and Kevin J. Stiroh, "Raising the Speed Limit: U.S. Economic Growth in the Information Age", Brookings Papers on Economic Activity, 1: 125-211, 2000.

—, Mun Ho and Kevin J. Stiroh, "Information Technology, Education, and the Sources of Economic Growth across U.S. Industries", downloadable at http://post.economics.harvard.edu/faculty/jorgenson/papers/jhscriw.pdf, March 2002.

Kirner, Wolfgang, Zeitreihen für das Anlagervermögen der Wirstchafsbereiche in der Bundesrepublik Deutschland, Deutsches Institut für Wirtschaftsforschung, Berlin, 1968.

Mason, Geoff, Catherine Robinson, John Forth and Mary O'Mahony, "Industry-level estimates of ICT and non-ICT employment, qualifications and wages in the U.K. and U.S.A, 1979-2000", NIESR, mimeographed, 2003.

Nordhaus, William D., "The Progress of Computing", Cowles Foundation Discussion Paper, No. 1324, September 2001.

Oliner, Steven D. and Daniel E. Sichel, "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story", Journal of Economic Perspectives, vol. 14, no.4, p. 3-22, Fall 2000.

—, —, "Information Technology and Productivity: Where Are We Now and Where Are We Going?", downloadable from http://www.federalreserve.gov/pubs/feds/2002/200229/200229pap.pdf May 2002.

O'Mahony, Mary, "Britain's Productivity Performance 1950-1996, An International Perspective", NIESR, mimeographed, 1999.

— and Willem de Boer, "Britain's relative productivity performance: Updates to 1999", Final Report to DTI/Treasury/ONS, mimeographed, 2001.

— and Bart van Ark (eds.), EU Productivity and Competitiveness: A Sectoral Perspective; Can Europe Resume the Catching-Up Process?, European Commission, Brussels, November 2003.

— and Michela Vecchi, "Is there an ICT impact on TFP? A heterogeneous dynamic panel approach", NIESR discussion paper, no. 219, 2003.

—, Catherine Robinson and Michela Vecchi, "The impact of ICT on the demand for skilled labour: evidence from the U.S., U.K. and France", downloadable from http://www.niesr.ac.uk/epke/WP-16.pdf, 2003.

Oulton, Nicholas, 'ICT and Productivity Growth in the United Kingdom', Bank of England Working Paper, No. 140, 2001.

Robinson, Catherine, Lucy Stokes, Edwin Stuivenwold and Bart van Ark, "Industry Structure and Taxonomies", in Mary O'Mahony and Bart van Ark (eds.) EU Productivity and Competitiveness: A Sectoral Perspective; Can Europe Resume the Catching-Up Process?, European Commission, Brussels, November 2003.

Schreyer, Paul, "The contribution of information and communication technology to output growth: a study of the G7 countries", STI Working Papers, 2000/2, OECD, Paris, 2000.

—, "Computer price indices and international growth and productivity comparisons" Review of Income and Wealth, vol. 48, no. 1, pp. 15-31, March 2002

Solow, Robert, "Technical Change and the Aggregate Production Function", Review of Economics and Statistics, vol. 39, pp. 312-320, 1957.

Stiroh, Kevin J., "Are ICT Spillovers Driving the New Economy?", Review of Income and Wealth 48(1), pp. 33-58, 2002a.

—, "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?", American Economic Review, vol. 92, no. 5, pp. 1559-1576, December 2002b.

Timmer, Marcel P., Gerard Ypma and Bart van Ark, "IT in the European Union: A driver of productivity divergence?", GGDC Research Memorandum, no. GD-67, September 2003.

United Nations Statistics Division, System of National Accounts, United Nations, New York, 1993.

van Ark, Bart, Johanna Melka, Nanno Mulder, Marcel P. Timmer and Gerard Ypma, G., "ICT Investment and Growth Accounts for the European Union, 1980-2000", GGGD Research Memorandum, no. GD-56, downloadable from: http://www.ggdc.net/pub/online/gd56-2(online).pdf, 2002.

—, Robert Inklaar, Robert H. McGuckin and Marcel P. Timmer "The employment effects of the 'new economy'. A comparison of the European Union and the United States", National Institute Economic Review, no. 184, April 2003a.

—, Robert Inklaar and Robert H. McGuckin, "'Changing Gear' Productivity, ICT and Service Industries: Europe and the United States", in Jens F. Christensen and Peter Maskell (eds.) The Industrial Dynamics of the New Digital Economy, Edward Elgar, Cheltenham, November 2003b.

—, Robert Inklaar and Robert H. McGuckin, "ICT and productivity in Europe and the United States, Where do the differences come from?", CESifo Economic Studies, vol. 49 no. 3 pp 295-318, Autumn 2003c.

Vijselaar, Focco and Ronald Albers "New Technologies and Productivity Growth in the Euro Area", ECB Working Paper, No. 122, European Central Bank, Frankfurt.

Appendix A Data and methods

Introduction

In this appendix we discuss the construction and data sources of our database in more detail. Value added, hours worked and compensation have been derived from the 60-industry database. Sources and methods of the 60-industry database is directly available at www.ggdc.net and will not be repeated here. Here we focus on the new additions to this database: investment and skill data We first give a more detailed overview of the characteristics of the data on employment by skill and investment by asset type. In the next part we discuss the detailed data sources and methods used in constructing the labour skill and investment data for each country.

Table A.1 Industries in the growth-accounting database

Number	*Industry*	*ISIC rev3 code*	*ICT classification*
1	Agriculture, forestry and fishing	01-05	N
2	Mining and quarrying	10-14	N
3	Food products	15-16	N
4	Textiles, clothing and leather	17-19	N
5	Wood products	20	N
6	Paper, printing and publishing	21-22	U
7	Petroleum and coal products	23	N
8	Chemical products	24	N
9	Rubber and plastics	25	N
10	Non-metalic mineral products	26	N
11	Metal products	27-28	N
12	Machinery	29	U
13	Electrical and electronic equipment & instruments	30-33	P
14	Transport equipment	34-35	N
15	Furniture and miscellaneous manufacturing	36-37	U
16	Electricity, gas and water	40-41	N
17	Construction	45	N
18	Wholesale trade	50-51	U
19	Retail trade	52	U
20	Hotels and restaurants	55	N
21	Transport & storage	60-63	N
22	Communications	64	P
23	Financial intermediation	65-67	U
24	Business services	71-74	U
25	Social and personal services	90-99	N
26	Non-market services	75-85	N

Notes: P: ICT producing industries, U: ICT using industries, N: Non-ICT industries

Labour Skills

Estimating labour quality requires total labour input to be divided into a number of categories of educational attainment (skill). Although educational classifications differ across countries, these disparities are not a major issue for examining the contribution to growth since the wage share weights the contribution from each skill group (with the implicit assumption that wages equal marginal products). As long as the number of skill groups does not vary too much across the countries and the divisions are roughly equivalent, then the relative wage shares pick up differences across countries in the growth in labour quality. There are additional complications if the calculations do not control for other impacts on wages such as gender, age, minimum wages and the impact of collective bargaining. The sample size in the survey data used in this study precludes the division of workers by age and gender – in addition to skills – by industry group. Similarly there is no information to take account of other influences that may cause deviations of wages from marginal products.

The number of labour skill types (based on educational attainment or qualifications) varies from three in Germany to seven in the Netherlands. Table A.2 summarises the categories included for each country but some further explanation is required.

The most transparent case is the U.S. where the division at the post-secondary level depends on the number of years of college attendance and/or whether a degree was awarded. Bachelor degrees and above in the U.S. are awarded after 3-4 years of study and tend to be dominated by academic subjects. Associate degrees are shorter, 2–3 years, and are dominated by vocational subjects areas. The final two categories distinguish those who have graduated from high school from others and so is more an attendance than an attainment measure.

The categories in the U.K. are somewhat different at the intermediate/lower end, but the first two categories in the U.K. ('first degrees and above' and 'Other NVQ4') are roughly equivalent to respectively the first U.S. category ('Bachelor degrees and above') and the second U.S. category ('Associate degrees'). The category NVQ3 includes school leavers who have achieved at least one pass at A-level and equivalent vocational qualifications. NVQ1 and 2 includes school leavers with passes in the main examinations taken at age 16 (GCSE) plus lower level vocational qualifications.

For France, the categories Bachelor degrees and Baccalaureate plus two years are again broadly equivalent to the U.S. bachelor degrees and above and associate degrees. Baccalaureate is similar to the U.K. A levels whereas the vocational qualifications can be achieved at a number of different levels. BEPC is similar to the U.K. GCSE.

In the case of the Netherlands, there are seven levels of educational attainment. Most students in academic subject areas have completed a master's degree or above. The next level down (HBO) is also tertiary education and leads to a bachelor's degree. MAVO/HAVO/VWO is general education, which normally leads to entry into a higher level, taking up 4 to 6 years of study after primary school. LBO/VBO and MBO are vocational schooling, taking up a maximum of 4 years after primary school. Primary schooling (the lowest category) ends at age 12. People in the final category have the lowest educational attainment which is completed primary schooling or below.

The German skill categories are the least satisfactory, as they only show a three way division into higher education, vocational and other. Although a finer classification is available for hours worked allowing in particular more detail in the two lowest groups, corresponding wage data are not available.

Table A.2 Skills categories used in this study

France	The Netherlands
1. Bachelor degrees and above	1. Master degree and above
2. Baccalaureate plus 2 years college	2. HBO
3. Baccalaureate	3. HAVO/VWO
4. Vocational(CAP, BEP ou autre de ce niveau CAP, BEP ou autre de ce niveau)	4. MAVO
5. General Educational (BEPC)	5. MBO
6. No formal qualifications (Aucun diplôme ou CEP)	6. LBO/VBO
	7. Primary education or below
US	**UK**
1. Bachelor degrees and above	1. First degrees and above
2. Associate degrees	2. Other NVQ4
3. Some college, no degree	3. NVQ3
4. High school graduate	4. NVQ2 and NVQ1
5. Did not complete high school	5. No formal qualifications
Germany	
1. Higher education (16-17 years education or above)	
2. Vocational degree	
3. No degree	

Capital asset types

In total six asset types are distinguished, including computing equipment, communication equipment, software, transport equipment, other non-ICT equipment, and non-residential structures and buildings (see Table A.3).[26] Residential buildings are not taken into account to allow for a sharper focus on the productivity contribution of business-related assets and facilitate the analysis of effects of ICT on capital and productivity growth. Consequently in the analysis of contributions of factor inputs to aggregate economic growth, the real estate sector (in which the imputed rents of residential buildings is recorded as part of output) is left out from both output and inputs.

[26] Note that computing equipment includes computers and peripherals, but excludes other office equipment in contrast to Timmer, Ypma and van Ark (2003).

Table A.3 Asset types in the growth-accounting database

Non-ICT assets
1. Non-residential buildings and structures
2. Transport equipment
3. Other non-ICT equipment
ICT assets
4. Computing equipment
5. Software
6. Communication equipment

Depreciation rates

Industry depreciation rates for non-ICT assets were derived using detailed depreciation rates for the U.S. for 62 assets. For each industry, these depreciation rates are weighted by current investment by asset to arrive at depreciation rates for each of the six assets from Table A.3. Although the number of asset types varied across industries, this was based on about three types of structures, ten types of non-ICT equipment and three types of transport equipment. This procedure captures differences in the composition of investment across industries. Deprecation rates were those given in Fraumeni (1997), except for automobiles, which was set equal to 0.272 taken from Jorgenson and Stiroh (2000).

The three ICT assets, computers, software and communications equipment were assumed to have the same depreciation rate for all industries. These were set equal to the rates employed in Jorgenson and Stiroh (2000), i.e. 0.315 for computers and software and 0.115 for communications equipment. Depreciation rates by industry are shown in Table A4. These depreciation rates were applied to all countries. The method assumes both that depreciation rates for specific assets are constant across countries, equal to those in the U.S., and that the asset composition within industries also does not vary across countries. Both assumptions are unlikely to be met in practice. However it is difficult to devise a workable alternative since there is very little reliable information on industry depreciation rates outside the U.S.

Table A.4 Geometric depreciation rates used in this study by asset type and industry

	ICT assets			Non-ICT assets		
	Computing equipment	Communication equipment	Software	Non-residental buildings and structures	Other non-ICT equipment	Transport equipment
1 Agriculture, forestry and fishing	0.315	0.115	0.315	0.024	0.131	0.190
2 Mining and quarrying	0.315	0.115	0.315	0.068	0.136	0.142
3 Food products	0.315	0.115	0.315	0.033	0.111	0.191
4 Textiles, clothing and leather	0.315	0.115	0.315	0.034	0.108	0.183
5 Wood products	0.315	0.115	0.315	0.033	0.113	0.186
6 Paper, printing and publishing	0.315	0.115	0.315	0.034	0.109	0.176
7 Petroleum and coal products	0.315	0.115	0.315	0.033	0.121	0.153
8 Chemical products	0.315	0.115	0.315	0.033	0.113	0.186
9 Rubber and plastics	0.315	0.115	0.315	0.033	0.114	0.212
10 Non-metalic mineral products	0.315	0.115	0.315	0.033	0.114	0.198
11 Metal products	0.315	0.115	0.315	0.033	0.113	0.185
12 Machinery	0.315	0.115	0.315	0.034	0.113	0.179
13 Electrical equipment & instruments	0.315	0.115	0.315	0.034	0.112	0.170
14 Transport equipment	0.315	0.115	0.315	0.034	0.113	0.174
15 Furniture and miscellaneous	0.315	0.115	0.315	0.034	0.113	0.200
16 Electricity, gas and water	0.315	0.115	0.315	0.022	0.091	0.195
17 Construction	0.315	0.115	0.315	0.024	0.122	0.203
18 Wholesale trade	0.315	0.115	0.315	0.037	0.140	0.196
19 Retail trade	0.315	0.115	0.315	0.032	0.133	0.220
20 Hotels and restaurants	0.315	0.115	0.315	0.028	0.140	0.211
21 Transport & storage	0.315	0.115	0.315	0.025	0.123	0.115
22 Communications	0.315	0.115	0.315	0.027	0.120	0.217
23 Financial intermediation	0.315	0.115	0.315	0.042	0.135	0.194
24 Business services	0.315	0.115	0.315	0.036	0.146	0.235
25 Other services	0.315	0.115	0.315	0.036	0.146	0.206
26 Non-market services	0.315	0.115	0.315	0.017	0.163	0.238

Compensation shares to weight factor inputs

The growth of labour and capital inputs is weighted according to their compensation share in total value added. The share of labour in value added includes an adjustment for compensation for self-employed and family workers. The standard approach is to impute compensation for self-employed on the basis of compensation for employees. The simplest assumption is to assume that both types of workers earn a similar compensation. However, a closer look at the figures for the U.S. provided by Jorgenson, Ho and Stiroh (2002) show that this assumption is not valid. On the basis of detailed data for the U.S. on wages of employees and self-employed by skill, gender and sex, it appears that compensation for self-employed is generally lower than for employees due to their particular characteristics (for example the educational attainment of self-employed is lower than for employees). On the basis of this information we assume that the compensation per self-employed person was 70 percent of the compensation per employee.[27]

In a few cases labour compensation was higher than total value added. This is possible in cases where an industry incurs losses, or when an industry receives significant net subsidies. In either case, TFP calculations become impossible, as compensation shares need to be positive to make economic sense. Therefore, the labour share was constrained to a maximum of 95%. In some cases rental prices become negative due to large swings in

[27] In the case of household services in the Netherlands, compensation per self-employed is assumed to be only 35% of the compensation per employee. This is due to the way Statistics Netherlands estimates labour input in this industry. A large part of the workers in this industry consist of informal small-job labourers whose earnings are well below that of formal employees, partly because they do not pay taxes or social security contributions.

investment deflators, for example in non-residential buildings. To avoid these cases, a lower bound has been put to the rental price of 0.05.

Data sources for skills and investment

France

Investment series

French investment series are predominantly based on a non-public dataset from the French Statistical Office, Insee received from CEPII. This dataset contains data on investment in current and constant 1995 prices in 11 assets in 41 industries between 1959 and 2001. In addition, for non-residential structures, non-ICT machinery, communication equipment and transport equipment data in constant prices is available back to 1846, but the growth rate across industries is assumed identical to aggregate investment in those assets.

To aggregate across assets we use Törnquist aggregation to calculate investment deflator changes. Investment is available for 41 industries, which corresponds to the F-level of aggregation of the NAF1993 (nomenclature d'activités française 1993). This classification is consistent with NACE and ISIC rev3 at the 1-digit level, but at the 2-digit level there are important differences, mainly in manufacturing. To adjust for these differences we use industrial survey data from the OECD Structural Statistics on Industry and Services (2003) for the period 1990-2000 and (for some industries) data from the OECD National Accounts (on the ISIC rev2 classification). Using these data we can calculate which part of investment in a certain F-level industry should be relocated to a different ISIC industry. So for example in 1995, 10% of investment in the mineral products industry (NAF FF1) is part of mining and quarrying (ISIC 10-14) and 90% is part of non-metallic mineral products (ISIC 26). As we do not have any more detailed information about the asset composition we have to assume the same distribution for both parts of the mineral products industry. To combine (parts) of different industries we use Törnquist aggregation to calculate investment deflator changes.

Hours worked by skill type and wages by skill type were unpublished data provided by the CEPII (and originally obtained from INSEE) under the EC 5th framework project 'Employment Prospects in the Knowledge Economy.

Germany

Investment series.

Investment series on the six asset types by industry in both current and constant prices were constructed for 1970 to 2001. The main problems relate to the linking of investment series for West Germany and unified Germany and the estimation of series for software and ICT-equipment. The starting point were unpublished investment series by asset type at the aggregate level for West Germany (1970-1991) and for Germany as a whole (1991-2001) from the Statistisches Bundesamt (see Timmer, Ypma and van Ark, 2003). These contained information for eight asset types, but not separately for software (which was included in "intangible investment") and for IT-equipment (which was included in "office, computing and accounting equipment"). Software was split off from total intangible investment at the aggregate level by using the average corresponding share from France, Finland and Italy. To split off office machinery from IT-equipment the U.S. industry-specific ratio by industry of IT-equipment to IT-equipment plus office equipment (IOT) was applied.

Investment by industry is available for West Germany (1970-1991) and for unified Germany (1991-2001) from the Statistisches Bundesamt. These datasets contain a breakdown into only two asset types, namely investment in structures and investment in equipment and other assets. For Germany as a whole, the industry detail was sufficient to distinguish the 26 industries until 2000. For 2001 it was necessary to extrapolate some industries using share development for previous years. For the pre-1991 series for West Germany the trade sector and the transport and communications sector were not split up into more disaggregated industries. To distinguish wholesale from retail trade and transport from communications investment data were used from the West German National Accounts of 1990. In these National Accounts, for example, wholesale trade and retail trade are separately distinguished, but trade and repair of motor vehicles are not.

To further disaggregate industry investment into asset types, the following procedures were used:

- Investment in transport equipment was derived using the average share of transport investment in total non-structures investment by industry for France, Netherlands, U.K. and U.S.
- Industry shares in aggregate communication equipment investment were derived using industry shares from the *Ifo Investitionenrechnung*, which covers 1970-1994 for West-Germany and 1995-1998 for Germany as a whole. Series for unified Germany from 1991-1994 were estimated by assuming industry shares in 1994 to be the same as in 1995 and then link with West-German shares for the period 1991-1994.
- A similar procedure as for communication equipment was used for Office, computing and accounting machinery (IOT), which includes IT-equipment. To split off IT-equipment, industry-specific ratios of IT to IOT for the U.S. were applied (see below for U.S. sources).
- Investment in software was derived using the average ratio of software investment to IT-equipment investment by industry for France, Netherlands, and the U.S.
- Investment in non-ICT equipment was calculated as a residual.[28]

To derive complete series for the period 1970-2001, growth rates of the West-Germany data to total Germany were linked in 1991. Historical investment data were derived from *Volkswirtschaftliche Gesamtrechnungen, 1950-1990* (Statistiches Bundesamt) and Kirner (1968). Initial capital stocks in 1970 were estimated for structures and equipment using historical information back to 1870 (structures) and 1960 (equipment).

<u>Labour quality</u>

Data on wage bills and employment for the three categories were from unpublished data received from Statistiches Bundesamt, originally from the German Employment Statistics and Wage and Salary Statistics.

[28] This led to balancing problems in the case of the communication industry between 1970 and 1991 (i.e. investment in Non-IT equipment was negative for most years). This was resolved by constraining Non-IT equipment investment to zero.

The Netherlands

Investment series

Investment series for 50 sectors and 20 asset types for the period 1949-2001 were obtained from unpublished data from Statistics Netherlands (March 2003) in both current and constant (2001) prices. Investment has been aggregated to 26 industries and 6 asset types using summation. Capital stocks for 1948 were available from the same source.

Labour quality

For employment shares by educational attainment for the period 1990-2000 we use the CBS, *Enquête Beroepsbevolking*, annual issues. Wages by educational type are provided by the CBS, *Loonstructuuronderzoek* for the years 1995, 1997 and 1998. For about 10 broad sectors reliable estimates could be derived. Due to small sample sizes a finer disaggregation was not possible. Consequently it is assumed that sub-sectors have the same educational attainment shares and relative wage structure as higher level aggregates.

U.K.

Investment series

Data series on the six asset types in both current and constant 1995 prices were constructed by industry from 1948 to 2000. Investment in computing equipment and software were assumed to begin in 1959, otherwise series were constructed for the entire sample period. The starting point was unpublished series by industry from the Office of National Statistics (ONS), which underlie their capital stock estimates. These series cover three asset types: structures, plant & machinery and vehicles. Plant & machinery includes computing equipment and communications equipment but not software.

Industry estimates of investment in all three ICT components were based on information on capital formation from input-output tables for selected years, with linear interpolation used to complete any missing years. This started with series for nominal investment in ICT for the total economy showing separately computers, software and communications equipment, and aggregate series on investment by industry from 1948 to 1999. The nominal aggregate series for computers and communications equipment were those reported in Oulton (2001) from 1974 onwards. Software is also based on Oulton's time series but the level in 1999 was derived in a different way using data on software sales from *The Computer Services Survey (Servcomm feasibility Survey) - data for 2000* (ONS, 2001), and adjusting for net exports and consumer spending on software. These three series were backdated to 1960 employing data on production and trade.

For each industry its share of total aggregate investment in ICT assets was estimated using 1992-1998 input output tables and data from investment surveys for 1999 and 2000. For prior years ICT shares were calculated by interpolating between periodic input output tables. Industry shares of investment in the three ICT assets were then applied to the aggregate series for the three types of ICT to yield industry nominal investment series. Full details of the method and additional sources are given in O'Mahony and de Boer (2001).

Labour quality

The U.K.'s labour force survey (LFS) contains matched information on wages and skill categories for labour force groups from 1992 onwards. Before 1992 wage data were not available so the LFS employment series were linked to wage trends from the General Household Survey. Further details on the construction of this dataset are available in Mason, Robinson, Forth and O'Mahony (2003).

U.S.

Investment series

Data series on the six asset types in both current and constant prices were constructed by industry from 1901 to 2001. The main problem is in mapping the U.S. industrial classification (U.S. SIC) and the ISIC revision 3 system used in this study. Therefore a two-stage procedure is used in which first total investment series for 56 ISIC rev 3 industries are constructed, which subsequently are broken down into the six asset types. To derive investment series for private industry, we use data from the National Income and Product Accounts (NIPA) on gross fixed capital formation (which contains data from 1901 onwards for 62 U.S. SIC industries). This information was supplemented with investment data from the *NBER Manufacturing Industry Database* (data available from 1958 onwards), the Census Bureau, *Annual Survey of Manufacturers 2001* and the BEA, *Capital Flow Table* for 1982 and 1992. The additional information was needed to match the 62 NIPA industries with the 56 industries distinguished in the 60-industry database.[29]

In a second step, aggregate investment is broken down by asset type. The BEA also provides a dataset on private investment by industry and type, which covers the 1901-2001 period. Total investment both by industry and by asset type is consistent with the more aggregated NIPA tables used in step 1 above. The BEA distinguishes 62 asset types for 62 industries. In the first step we aggregate the 62 asset types to six types. Since the BEA table contains more detail in some industries than required for this purpose, the 62 industries were aggregated to 40. For each of the 56 industries distinguished in step 1, the asset investment composition of the appropriate BEA 40-industry classification was used. So, for example, the computer industry gets the same asset composition as other industrial machinery.

Government investment is contained in separate NIPA tables. Although the NIPA classify a wide range of defence purchases as investment, most were excluded to ensure consistency with national accounts in other countries and the SNA93. This means 'destructive' assets such as planes and tanks are excluded while 'dual-use' assets like military hospitals are included. The asset composition of government investment is less extensive than for other industries so one can only separately distinguish non-residential and other investment. The asset composition from other non-market services (health and education) is

29 Additional data is used to reallocate the computer industry from machinery to electrical and electronics, to move restaurants out of retail trade and combine it with hotels and to reallocate radio and TV broadcasting from communications to community, social and personal services. This does not resolve all classification problems but it solves the most pressing ones. For some manufacturing industries not separately identified in the NIPA, extrapolations had to be made for the period before 1958. However, these extrapolations will not generally have a large impact as they mostly involve the pre-1958 period and industries like computers, which were marginal before that date.

applied to break the 'other' investment down into non-IT equipment, transport equipment, IT-equipment, communication equipment and software.

The final step is to aggregate across the 56 industries to arrive at the 26-industry classification used in this study. In all aggregation steps current investment was summed and Törnquist aggregation was used to obtain the investment deflators.

Labour quality

Skill shares in total employment by industry and relative wage levels are derived from the U.S. Current Population Survey (CPS). Crucially for the purposes of this study, the CPS contains matched information on wages and skill categories for labour skill groups. The CPS data set extends back to 1976, although adjustments were required to yield series based on consistent definitions throughout. For example, years of education was replaced in 1992 by variables that were a mixture of attainment and qualifications. So use was made of a matrix that had both series for an overlapping survey. Further details on the construction of this dataset are available in Mason *et al.* (2003).

Appendix B Extra Tables and Figures

Table B.1 Industry contributions to agrgegate labour productivity growth, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.25	0.10	0.19	0.07	0.12	0.13
Mining and quarrying	0.02	0.02	-0.18	0.53	0.13	0.11
Food products	0.04	0.05	0.15	0.12	0.06	0.04
Textiles, clothing and leather	0.03	0.04	0.03	0.05	0.04	0.04
Wood products	0.01	0.01	0.01	0.00	0.01	0.01
Paper, printing and publishing	0.04	0.04	0.08	0.07	0.05	-0.02
Petroleum and coal products	-0.12	-0.01	0.03	0.01	-0.03	0.04
Chemical products	0.09	0.12	0.14	0.16	0.13	0.07
Rubber and plastics	0.01	0.03	0.02	0.03	0.03	0.03
Non-metalic mineral products	0.04	0.03	0.02	0.03	0.03	0.01
Metal products	0.05	0.09	0.06	0.11	0.09	0.05
Machinery	0.07	0.07	0.04	0.05	0.07	-0.01
Electrical and electronic equipment & instruments	0.23	0.26	0.20	0.41	0.28	0.46
Transport equipment	0.10	0.08	0.04	0.16	0.10	0.02
Furniture and miscellaneous manufacturing	0.03	0.00	0.04	0.00	0.01	0.02
Electricity, gas and water	0.12	0.05	0.05	0.17	0.11	0.04
Construction	0.15	-0.03	0.13	0.15	0.08	-0.02
Wholesale trade	0.22	0.14	0.20	0.21	0.17	0.17
Retail trade	0.17	0.09	0.09	0.09	0.10	0.19
Hotels and restaurants	-0.06	-0.02	-0.01	-0.01	-0.03	-0.03
Transport & storage	0.13	0.12	0.10	0.20	0.13	0.05
Communications	0.15	0.16	0.05	0.15	0.16	0.04
Financial intermediation	0.18	0.14	0.09	0.03	0.12	0.02
Business services	0.11	0.12	0.00	0.08	0.11	0.01
Social and personal services	-0.09	0.03	0.05	0.10	0.02	0.03
Non-market services	0.30	0.17	0.27	0.04	0.19	-0.13
Reallocation of hours	0.22	0.19	0.17	-0.50	0.02	-0.15
Total economy	2.50	2.07	2.05	2.48	2.30	1.21

Table B.2 Industry contributions to agrgegate labour productivity growth, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.17	0.09	0.08	0.04	0.08	0.19
Mining and quarrying	0.03	-0.01	0.09	0.02	0.06	0.00
Food products	-0.03	0.02	0.05	-0.02	0.00	-0.10
Textiles, clothing and leather	0.04	0.02	0.04	0.01	0.03	0.02
Wood products	0.01	0.01	0.01	0.00	0.01	-0.01
Paper, printing and publishing	0.05	0.07	0.09	0.00	0.04	0.02
Petroleum and coal products	-0.01	0.03	-0.04	-0.02	0.00	0.02
Chemical products	0.13	0.07	0.10	0.08	0.09	0.05
Rubber and plastics	0.03	0.01	0.03	0.00	0.02	0.03
Non-metalic mineral products	0.03	0.01	0.03	0.01	0.02	0.01
Metal products	0.04	0.05	0.04	0.03	0.04	0.03
Machinery	0.05	0.04	0.05	0.00	0.04	0.00
Electrical and electronic equipment & instruments	0.25	0.32	-0.03	0.44	0.31	0.73
Transport equipment	0.13	-0.11	0.04	0.01	0.00	0.03
Furniture and miscellaneous manufacturing	0.02	0.01	0.03	0.00	0.01	0.02
Electricity, gas and water	0.09	0.16	0.07	0.25	0.17	0.06
Construction	-0.08	0.07	0.01	0.07	0.03	-0.01
Wholesale trade	0.02	0.13	0.46	0.39	0.18	0.52
Retail trade	0.08	0.05	0.09	0.13	0.08	0.48
Hotels and restaurants	0.03	-0.06	0.02	-0.09	-0.04	0.00
Transport & storage	0.04	0.15	0.16	0.34	0.15	0.09
Communications	0.21	0.47	0.21	0.29	0.34	0.16
Financial intermediation	0.01	0.26	0.00	0.22	0.17	0.45
Business services	-0.05	-0.11	0.14	0.32	0.07	-0.07
Social and personal services	-0.03	0.00	-0.01	0.05	0.00	-0.05
Non-market services	0.22	0.12	0.11	0.20	0.18	-0.14
Reallocation of hours	0.04	0.21	-0.34	-0.17	-0.04	-0.09
Total economy	1.55	2.08	1.52	2.59	2.02	2.46

Table B.3 Contribution to aggregate labour productivity growth of industry labour quality growth, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.00	0.00	0.00	0.01	0.01	0.00
Food products	0.01	0.01	0.00	0.02	0.01	0.01
Textiles, clothing and leather	0.00	0.00	0.00	0.01	0.00	0.01
Wood products	0.00	0.00	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.01	0.01	0.00	0.00	0.01	0.01
Petroleum and coal products	0.00	0.00	0.00	0.00	0.00	0.00
Chemical products	0.01	0.01	0.00	0.01	0.01	0.00
Rubber and plastics	0.00	0.00	0.00	0.00	0.00	0.00
Non-metalic mineral products	0.00	0.00	0.00	0.00	0.00	0.00
Metal products	0.01	0.01	0.00	0.01	0.02	0.01
Machinery	0.01	0.02	0.00	0.01	0.02	0.01
Electrical and electronic equipment & instruments	0.01	0.02	0.00	0.02	0.02	0.03
Transport equipment	0.01	0.01	0.00	0.01	0.02	0.01
Furniture and miscellaneous manufacturing	0.00	0.00	0.00	0.00	0.00	0.00
Electricity, gas and water	0.00	0.00	0.00	0.01	0.01	0.00
Construction	0.01	0.01	0.00	0.01	0.01	0.00
Wholesale trade	0.00	0.02	0.01	0.03	0.01	0.02
Retail trade	0.01	0.01	0.01	0.03	0.01	0.01
Hotels and restaurants	0.00	0.01	0.00	0.02	0.01	0.00
Transport & storage	0.01	0.00	0.00	0.07	0.02	0.01
Communications	-0.01	0.01	0.00	0.01	0.01	0.01
Financial intermediation	0.01	0.01	0.01	0.02	0.01	0.03
Business services	0.02	0.01	0.01	0.01	0.01	0.03
Social and personal services	0.01	0.01	0.00	0.04	0.01	0.02
Non-market services	0.05	0.06	0.03	0.13	0.08	0.06
Total economy	0.18	0.26	0.08	0.50	0.31	0.28

Table B.4 Contribution to aggregate labour productivity growth of industry labour quality growth, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.01	0.00	0.00	0.00	0.00	0.00
Food products	0.01	0.00	0.01	0.01	0.00	0.00
Textiles, clothing and leather	0.00	0.00	0.00	0.01	0.00	0.00
Wood products	0.00	0.00	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.00	0.00	0.00	0.01	0.00	0.00
Petroleum and coal products	0.00	0.00	0.00	0.00	0.00	0.00
Chemical products	0.01	0.00	0.00	0.01	0.01	0.00
Rubber and plastics	0.00	0.00	0.00	0.00	0.00	0.00
Non-metalic mineral products	0.00	0.00	0.00	0.00	0.00	0.00
Metal products	0.00	0.00	0.00	0.00	0.00	0.00
Machinery	0.00	0.00	0.00	0.00	0.01	0.01
Electrical and electronic equipment & instruments	0.01	0.01	0.00	0.01	0.01	0.01
Transport equipment	0.01	0.00	0.00	0.01	0.01	0.01
Furniture and miscellaneous manufacturing	0.00	0.00	0.00	0.00	0.00	0.00
Electricity, gas and water	0.01	0.00	0.00	0.00	0.00	0.00
Construction	0.02	0.00	0.00	0.02	0.01	0.01
Wholesale trade	0.03	0.01	0.00	0.02	0.01	0.01
Retail trade	0.03	0.00	0.00	0.01	0.01	0.01
Hotels and restaurants	0.00	0.00	0.00	0.01	0.00	0.00
Transport & storage	0.02	0.00	0.01	0.00	0.00	0.01
Communications	0.01	0.01	0.01	0.02	0.01	0.01
Financial intermediation	0.00	0.00	0.03	0.03	0.01	0.01
Business services	0.06	0.00	0.05	0.08	0.04	0.03
Social and personal services	0.02	0.00	-0.01	0.02	0.01	0.01
Non-market services	0.13	-0.01	0.02	0.12	0.06	0.08
Total economy	0.40	0.05	0.14	0.41	0.22	0.22

Table B.5 Contribution to aggregate labour productivity growth of industry ICT capital deepening, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.00	0.00	0.01	0.01	0.00	0.01
Food products	0.00	0.01	0.01	0.01	0.01	0.01
Textiles, clothing and leather	0.00	0.00	0.00	0.00	0.00	0.00
Wood products	0.00	0.00	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.00	0.01	0.01	0.01	0.01	0.01
Petroleum and coal products	0.00	0.01	0.00	0.00	0.00	0.00
Chemical products	0.00	0.02	0.02	0.01	0.01	0.01
Rubber and plastics	0.00	0.00	0.00	0.00	0.00	0.00
Non-metalic mineral products	0.00	0.00	0.00	0.01	0.00	0.00
Metal products	0.00	0.00	0.01	0.00	0.00	0.00
Machinery	0.00	0.01	0.00	0.00	0.01	0.01
Electrical and electronic equipment & instruments	0.01	0.02	0.01	0.02	0.01	0.04
Transport equipment	0.00	0.02	0.00	0.00	0.01	0.01
Furniture and miscellaneous manufacturing	0.00	0.00	0.00	0.00	0.00	0.00
Electricity, gas and water	0.01	0.01	0.00	0.01	0.01	0.01
Construction	0.00	0.01	0.01	0.01	0.01	0.00
Wholesale trade	0.01	0.02	0.05	0.06	0.03	0.08
Retail trade	0.01	0.01	0.01	0.03	0.01	0.04
Hotels and restaurants	0.00	0.00	0.00	0.00	0.00	0.00
Transport & storage	0.01	0.00	0.01	0.01	0.00	0.01
Communications	0.01	0.04	0.01	0.02	0.03	0.02
Financial intermediation	0.07	0.07	0.13	0.08	0.08	0.11
Business services	0.01	0.11	0.02	0.05	0.07	0.04
Social and personal services	0.00	0.01	0.00	0.00	0.01	0.01
Non-market services	0.01	0.01	0.02	0.01	0.01	0.03
Total economy	0.16	0.39	0.35	0.38	0.33	0.46

Table B.6 Contribution to aggregate labour productivity growth of industry ICT capital deepening, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.00	0.00	0.00	0.00	0.00	0.00
Mining and quarrying	0.00	0.00	0.01	0.00	0.00	0.00
Food products	0.01	0.01	0.02	0.00	0.01	0.01
Textiles, clothing and leather	0.00	0.00	0.00	0.01	0.00	0.00
Wood products	0.00	0.00	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.01	0.02	0.02	0.02	0.01	0.02
Petroleum and coal products	0.00	0.00	0.00	0.00	0.00	0.00
Chemical products	0.01	0.01	0.00	0.02	0.01	0.02
Rubber and plastics	0.00	0.00	0.00	0.01	0.00	0.00
Non-metalic mineral products	0.00	0.00	0.00	0.00	0.00	0.00
Metal products	0.00	0.00	0.01	0.01	0.01	0.01
Machinery	0.00	0.01	0.01	0.02	0.01	0.01
Electrical and electronic equipment & instruments	0.01	0.01	0.02	0.04	0.02	0.05
Transport equipment	0.01	0.01	0.00	0.00	0.00	0.01
Furniture and miscellaneous manufacturing	0.00	0.00	0.00	0.01	0.00	0.00
Electricity, gas and water	0.02	0.02	0.01	0.01	0.02	0.01
Construction	0.00	0.01	0.03	0.00	0.01	0.02
Wholesale trade	0.02	0.05	0.08	0.18	0.07	0.13
Retail trade	0.02	0.03	0.02	0.04	0.03	0.05
Hotels and restaurants	0.01	0.00	0.00	0.00	0.00	0.00
Transport & storage	0.01	0.01	0.01	0.02	0.01	0.02
Communications	0.02	0.05	0.03	0.09	0.05	0.05
Financial intermediation	0.09	0.10	0.19	0.07	0.10	0.27
Business services	0.02	0.15	0.07	0.16	0.12	0.09
Social and personal services	0.01	0.02	0.01	0.01	0.01	0.03
Non-market services	0.01	0.02	0.04	0.01	0.02	0.04
Total economy	0.30	0.53	0.61	0.72	0.53	0.86

Table B.7 Contribution to aggregate labour productivity growth of industry non-ICT capital deepening, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.10	0.00	0.05	0.01	0.03	0.00
Mining and quarrying	0.01	0.01	0.03	0.48	0.13	0.10
Food products	0.05	0.01	0.04	0.03	0.03	0.01
Textiles, clothing and leather	0.02	0.02	0.00	0.01	0.01	0.00
Wood products	0.00	0.00	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.03	0.02	0.02	0.02	0.02	0.01
Petroleum and coal products	0.03	-0.01	0.02	0.01	0.01	0.01
Chemical products	0.04	0.01	0.04	0.03	0.03	0.02
Rubber and plastics	0.00	0.00	0.00	0.00	0.00	0.00
Non-metalic mineral products	0.01	0.01	0.01	0.02	0.01	0.00
Metal products	0.03	0.01	0.01	0.01	0.02	0.01
Machinery	0.03	0.01	0.00	0.01	0.02	0.01
Electrical and electronic equipment & instruments	0.05	0.03	0.01	0.04	0.04	0.04
Transport equipment	0.02	0.03	0.00	0.02	0.03	0.00
Furniture and miscellaneous manufacturing	0.01	0.01	0.00	0.01	0.01	0.00
Electricity, gas and water	0.02	0.04	0.03	0.08	0.05	0.02
Construction	0.05	-0.02	0.03	0.01	0.01	-0.02
Wholesale trade	0.03	0.00	0.02	0.05	0.02	0.04
Retail trade	0.03	0.01	0.01	0.05	0.02	0.04
Hotels and restaurants	0.02	0.00	0.00	0.03	0.01	0.00
Transport & storage	0.02	0.00	0.02	0.02	0.01	-0.02
Communications	0.02	0.05	0.03	0.04	0.04	0.02
Financial intermediation	-0.01	0.05	0.06	0.05	0.03	0.08
Business services	-0.17	0.16	-0.04	0.10	0.05	-0.04
Social and personal services	-0.04	0.05	0.05	0.02	0.02	0.01
Non-market services	-0.01	0.06	0.06	0.03	0.04	0.03
Total economy	0.39	0.55	0.50	1.15	0.70	0.35

Table B.8 Contribution to aggregate labour productivity growth of industry non-ICT capital deepening, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.07	0.01	0.03	0.01	0.03	0.02
Mining and quarrying	0.00	0.00	0.10	-0.03	0.04	0.02
Food products	-0.01	-0.01	0.02	0.00	-0.01	0.01
Textiles, clothing and leather	0.01	0.00	0.00	0.01	0.01	0.01
Wood products	0.00	0.00	0.00	0.00	0.00	0.00
Paper, printing and publishing	0.01	0.02	0.02	-0.01	0.01	0.01
Petroleum and coal products	0.01	0.00	0.01	-0.01	0.00	0.00
Chemical products	0.04	0.02	0.05	0.02	0.03	0.03
Rubber and plastics	0.00	0.01	0.00	0.00	0.01	0.01
Non-metalic mineral products	0.01	0.01	0.01	0.01	0.01	0.01
Metal products	0.00	0.01	0.01	0.01	0.01	0.00
Machinery	0.01	0.00	0.00	0.00	0.00	0.00
Electrical and electronic equipment & instruments	0.00	-0.01	0.00	0.03	0.01	0.04
Transport equipment	0.00	-0.01	-0.01	0.01	0.00	0.01
Furniture and miscellaneous manufacturing	0.00	0.00	0.00	0.01	0.01	0.00
Electricity, gas and water	0.00	0.07	0.08	0.13	0.08	0.04
Construction	0.00	0.01	0.03	0.03	0.01	0.01
Wholesale trade	-0.01	0.01	0.01	0.02	0.01	0.03
Retail trade	0.00	0.01	0.01	0.03	0.01	0.04
Hotels and restaurants	0.01	0.00	-0.01	0.04	0.01	0.01
Transport & storage	-0.02	0.00	0.01	0.02	0.00	0.01
Communications	0.00	0.06	0.04	0.01	0.02	0.02
Financial intermediation	-0.01	0.03	0.02	-0.03	0.00	0.08
Business services	-0.30	-0.04	-0.03	0.01	-0.07	-0.06
Social and personal services	-0.04	0.01	-0.02	0.00	-0.01	0.02
Non-market services	0.00	0.04	0.01	0.04	0.03	0.04
Total economy	-0.19	0.28	0.41	0.35	0.25	0.43

Table B.9 Contribution to aggregate labour productivity growth of industry TFP growth, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.15	0.10	0.14	0.05	0.09	0.13
Mining and quarrying	0.01	0.01	-0.23	0.04	-0.01	0.00
Food products	-0.02	0.02	0.10	0.05	0.02	0.02
Textiles, clothing and leather	0.00	0.02	0.02	0.03	0.02	0.03
Wood products	0.01	0.01	0.01	0.00	0.01	0.01
Paper, printing and publishing	0.00	0.00	0.04	0.03	0.01	-0.05
Petroleum and coal products	-0.15	-0.01	0.01	-0.01	-0.05	0.02
Chemical products	0.04	0.08	0.08	0.11	0.08	0.03
Rubber and plastics	0.01	0.01	0.02	0.02	0.02	0.03
Non-metalic mineral products	0.03	0.02	0.01	0.00	0.02	0.01
Metal products	0.02	0.07	0.03	0.08	0.05	0.03
Machinery	0.03	0.02	0.03	0.02	0.02	-0.04
Electrical and electronic equipment & instruments	0.16	0.18	0.18	0.34	0.21	0.36
Transport equipment	0.07	0.02	0.04	0.13	0.05	0.01
Furniture and miscellaneous manufacturing	0.02	-0.01	0.04	-0.01	0.00	0.01
Electricity, gas and water	0.09	0.00	0.02	0.07	0.04	0.00
Construction	0.09	-0.03	0.09	0.12	0.05	-0.02
Wholesale trade	0.17	0.10	0.11	0.07	0.11	0.04
Retail trade	0.13	0.06	0.07	-0.03	0.06	0.10
Hotels and restaurants	-0.09	-0.03	-0.02	-0.06	-0.05	-0.03
Transport & storage	0.09	0.11	0.07	0.10	0.09	0.05
Communications	0.13	0.05	0.01	0.08	0.09	-0.01
Financial intermediation	0.12	0.01	-0.10	-0.11	0.00	-0.19
Business services	0.26	-0.17	0.02	-0.09	-0.03	-0.02
Social and personal services	-0.07	-0.03	0.00	0.05	-0.02	0.00
Non-market services	0.25	0.03	0.16	-0.13	0.07	-0.24
Total economy	1.55	0.67	0.95	0.95	0.94	0.26

Table B.10 Contribution to aggregate labour productivity growth of industry TFP growth, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.10	0.08	0.05	0.02	0.06	0.16
Mining and quarrying	0.02	-0.01	-0.03	0.06	0.01	-0.02
Food products	-0.03	0.02	0.01	-0.03	-0.01	-0.13
Textiles, clothing and leather	0.02	0.01	0.03	-0.01	0.01	0.01
Wood products	0.01	0.01	0.00	0.00	0.00	-0.01
Paper, printing and publishing	0.03	0.02	0.04	-0.01	0.02	-0.01
Petroleum and coal products	-0.02	0.03	-0.06	-0.01	0.00	0.01
Chemical products	0.06	0.03	0.05	0.03	0.04	0.00
Rubber and plastics	0.02	0.01	0.02	-0.01	0.01	0.02
Non-metalic mineral products	0.02	0.00	0.02	0.00	0.01	0.00
Metal products	0.03	0.03	0.02	0.01	0.03	0.02
Machinery	0.03	0.03	0.03	-0.02	0.02	-0.02
Electrical and electronic equipment & instruments	0.23	0.30	-0.06	0.37	0.27	0.63
Transport equipment	0.11	-0.11	0.05	-0.01	-0.01	0.01
Furniture and miscellaneous manufacturing	0.02	0.00	0.02	-0.01	0.00	0.02
Electricity, gas and water	0.06	0.07	-0.02	0.10	0.08	0.00
Construction	-0.10	0.05	-0.05	0.02	0.00	-0.04
Wholesale trade	-0.02	0.06	0.37	0.17	0.08	0.35
Retail trade	0.04	0.01	0.05	0.05	0.03	0.39
Hotels and restaurants	0.02	-0.06	0.03	-0.15	-0.06	-0.01
Transport & storage	0.02	0.14	0.12	0.30	0.13	0.05
Communications	0.18	0.36	0.13	0.18	0.26	0.08
Financial intermediation	-0.07	0.13	-0.24	0.15	0.06	0.08
Business services	0.17	-0.22	0.05	0.07	-0.02	-0.12
Social and personal services	-0.03	-0.03	0.01	0.02	-0.02	-0.11
Non-market services	0.08	0.07	0.04	0.03	0.07	-0.30
Total economy	1.01	1.02	0.70	1.28	1.07	1.05

Table B.11 Industry contributions to aggregate ICT capital deepening, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.02	0.01	0.09	0.09	0.02	0.04
Mining and quarrying	0.05	0.04	0.95	0.48	0.16	0.38
Food products	0.32	0.17	0.58	0.92	0.28	0.21
Textiles, clothing and leather	0.07	0.01	0.04	0.07	0.03	0.07
Wood products	0.01	0.02	0.01	0.02	0.02	0.06
Paper, printing and publishing	0.22	0.31	0.73	0.40	0.34	0.34
Petroleum and coal products	0.27	0.19	0.27	0.17	0.21	0.05
Chemical products	0.33	0.42	1.02	0.46	0.44	0.31
Rubber and plastics	0.07	0.10	0.05	0.10	0.10	0.03
Non-metalic mineral products	0.03	0.06	0.12	0.56	0.12	0.04
Metal products	0.17	0.07	0.87	0.19	0.16	0.17
Machinery	0.28	0.31	0.24	0.23	0.30	0.39
Electrical and electronic equipment & instruments	0.42	0.53	0.44	1.08	0.60	1.26
Transport equipment	0.13	0.47	0.12	0.23	0.37	0.23
Furniture and miscellaneous manufacturing	0.13	0.07	0.03	0.06	0.07	0.07
Electricity, gas and water	0.52	0.19	0.15	0.70	0.36	0.45
Construction	0.23	0.15	0.53	0.44	0.24	0.12
Wholesale trade	0.57	0.49	3.41	3.80	1.07	2.42
Retail trade	0.50	0.36	0.36	1.68	0.55	1.32
Hotels and restaurants	0.36	0.00	0.07	0.13	0.07	0.08
Transport & storage	0.39	0.02	0.38	0.21	0.12	0.17
Communications	0.84	1.19	0.53	1.31	1.10	0.80
Financial intermediation	4.83	2.01	8.18	5.08	3.29	3.24
Business services	0.67	3.45	0.86	2.57	3.13	1.28
Social and personal services	0.40	0.22	0.27	0.07	0.27	0.37
Non-market services	0.41	0.35	1.20	0.54	0.49	0.77
Total economy	12.27	11.20	21.50	21.60	13.92	14.65

Table B.12 Industry contributions to aggregate ICT capital deepening, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.06	0.02	0.15	0.04	0.03	0.05
Mining and quarrying	0.02	0.00	0.49	-0.02	0.05	0.08
Food products	0.27	0.16	0.57	0.07	0.16	0.16
Textiles, clothing and leather	0.12	0.00	0.05	0.14	0.07	0.06
Wood products	0.04	0.03	0.03	0.04	0.04	0.03
Paper, printing and publishing	0.27	0.47	0.87	0.45	0.44	0.37
Petroleum and coal products	0.12	-0.05	-0.03	0.00	-0.01	0.01
Chemical products	0.67	0.37	0.15	0.38	0.39	0.34
Rubber and plastics	0.17	0.11	0.06	0.13	0.14	0.05
Non-metalic mineral products	0.15	0.08	0.12	0.06	0.09	0.05
Metal products	0.26	0.10	0.29	0.19	0.17	0.14
Machinery	0.27	0.17	0.40	0.43	0.28	0.19
Electrical and electronic equipment & instruments	0.33	0.34	0.68	1.01	0.56	1.06
Transport equipment	0.38	0.14	0.10	0.08	0.14	0.18
Furniture and miscellaneous manufacturing	0.13	0.06	0.10	0.14	0.11	0.08
Electricity, gas and water	1.17	0.41	0.22	0.28	0.48	0.16
Construction	0.27	0.38	0.89	0.10	0.30	0.33
Wholesale trade	1.06	1.25	2.82	4.43	2.24	2.50
Retail trade	0.90	0.88	0.77	0.91	0.83	0.97
Hotels and restaurants	0.46	0.00	0.10	0.02	0.07	0.07
Transport & storage	0.66	0.24	0.42	0.49	0.35	0.35
Communications	0.83	1.35	1.17	2.27	1.47	0.99
Financial intermediation	4.97	2.60	6.60	1.80	3.07	5.26
Business services	1.29	4.17	2.44	3.96	3.73	1.64
Social and personal services	0.78	0.41	0.41	0.14	0.38	0.62
Non-market services	0.51	0.48	1.34	0.28	0.50	0.85
Total economy	16.15	14.19	21.22	17.82	16.08	16.57

Table B.13 Industry contributions to aggregate non-ICT capital deepening, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.34	0.02	0.15	0.04	0.12	-0.02
Mining and quarrying	0.03	0.03	0.09	1.78	0.47	0.39
Food products	0.18	0.06	0.12	0.12	0.10	0.05
Textiles, clothing and leather	0.06	0.06	0.01	0.04	0.05	0.02
Wood products	0.01	0.00	0.00	0.00	0.00	-0.01
Paper, printing and publishing	0.11	0.08	0.07	0.09	0.09	0.03
Petroleum and coal products	0.12	-0.02	0.05	0.05	0.04	0.05
Chemical products	0.15	0.03	0.11	0.11	0.10	0.08
Rubber and plastics	0.01	0.01	0.00	0.02	0.01	0.00
Non-metalic mineral products	0.02	0.04	0.03	0.06	0.04	0.00
Metal products	0.09	0.03	0.04	0.04	0.07	0.04
Machinery	0.13	0.06	0.00	0.04	0.07	0.02
Electrical and electronic equipment & instruments	0.17	0.14	0.03	0.15	0.15	0.15
Transport equipment	0.08	0.11	0.01	0.06	0.10	0.00
Furniture and miscellaneous manufacturing	0.05	0.03	0.00	0.02	0.03	0.00
Electricity, gas and water	0.09	0.14	0.10	0.31	0.18	0.09
Construction	0.16	-0.09	0.10	0.04	0.05	-0.06
Wholesale trade	0.12	0.01	0.08	0.17	0.08	0.16
Retail trade	0.09	0.02	0.03	0.19	0.07	0.16
Hotels and restaurants	0.07	0.00	0.01	0.10	0.04	0.01
Transport & storage	0.08	0.01	0.05	0.08	0.06	-0.07
Communications	0.07	0.18	0.08	0.14	0.14	0.08
Financial intermediation	-0.05	0.19	0.18	0.17	0.11	0.32
Business services	-0.60	0.61	-0.12	0.38	0.20	-0.18
Social and personal services	-0.12	0.19	0.14	0.08	0.09	0.02
Non-market services	-0.05	0.25	0.17	0.13	0.14	0.11
Total economy	1.40	2.17	1.56	4.41	2.59	1.46

Table B.14 Industry contributions to aggregate non-ICT capital deepening, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.24	0.03	0.09	0.04	0.09	0.10
Mining and quarrying	0.00	0.00	0.32	-0.13	0.13	0.10
Food products	-0.04	-0.03	0.07	-0.01	-0.02	0.06
Textiles, clothing and leather	0.05	0.02	0.01	0.03	0.03	0.04
Wood products	0.01	0.02	0.01	0.00	0.01	0.00
Paper, printing and publishing	0.04	0.09	0.05	-0.04	0.04	0.04
Petroleum and coal products	0.02	0.01	0.04	-0.02	0.00	0.01
Chemical products	0.13	0.08	0.15	0.07	0.11	0.14
Rubber and plastics	0.02	0.02	0.01	0.01	0.02	0.03
Non-metalic mineral products	0.03	0.03	0.03	0.03	0.03	0.02
Metal products	0.01	0.02	0.02	0.03	0.03	-0.01
Machinery	0.03	0.01	0.01	-0.01	0.02	0.01
Electrical and electronic equipment & instruments	0.01	-0.02	0.01	0.10	0.03	0.18
Transport equipment	0.02	-0.02	-0.02	0.02	0.00	0.02
Furniture and miscellaneous manufacturing	0.00	0.01	0.01	0.04	0.02	0.01
Electricity, gas and water	0.01	0.27	0.26	0.49	0.27	0.17
Construction	-0.01	0.03	0.09	0.12	0.05	0.06
Wholesale trade	-0.02	0.03	0.02	0.07	0.02	0.11
Retail trade	0.00	0.04	0.04	0.12	0.05	0.17
Hotels and restaurants	0.02	-0.01	-0.03	0.16	0.03	0.04
Transport & storage	-0.06	0.01	0.04	0.07	0.01	0.06
Communications	-0.01	0.21	0.14	0.02	0.07	0.09
Financial intermediation	-0.03	0.11	0.07	-0.12	0.00	0.35
Business services	-0.98	-0.15	-0.09	0.05	-0.24	-0.24
Social and personal services	-0.13	0.05	-0.06	0.01	-0.04	0.06
Non-market services	0.01	0.16	0.02	0.15	0.11	0.16
Total economy	-0.63	1.03	1.27	1.31	0.88	1.79

Table B.15 Share of ICT capital in value added, 1979-1995

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.03	0.10	0.17	0.47	0.14	0.30
Mining and quarrying	0.66	0.75	1.41	0.77	0.88	1.37
Food products	0.80	1.86	1.39	2.43	1.65	2.09
Textiles, clothing and leather	0.38	0.23	0.70	0.40	0.35	1.23
Wood products	0.38	0.72	0.40	0.53	0.58	1.38
Paper, printing and publishing	0.87	3.74	2.39	1.12	2.25	2.75
Petroleum and coal products	1.31	12.71	3.33	1.51	5.00	1.64
Chemical products	1.24	2.80	2.86	1.77	2.25	2.73
Rubber and plastics	0.53	2.28	0.99	0.89	1.40	0.99
Non-metalic mineral products	0.42	1.47	1.08	4.43	1.78	1.39
Metal products	0.53	0.63	2.51	0.64	0.73	1.16
Machinery	1.06	1.59	1.96	0.90	1.41	3.65
Electrical and electronic equipment & instruments	1.14	3.14	2.57	3.66	2.75	6.55
Transport equipment	0.62	2.40	0.79	0.85	1.76	1.70
Furniture and miscellaneous manufacturing	1.25	2.22	0.22	0.84	1.48	2.17
Electricity, gas and water	2.23	1.47	0.49	2.08	1.79	3.50
Construction	0.39	0.63	0.69	0.91	0.65	0.36
Wholesale trade	1.14	1.82	3.30	4.95	2.49	5.51
Retail trade	1.32	2.07	0.79	3.54	2.10	2.79
Hotels and restaurants	1.33	0.10	0.32	0.50	0.65	0.81
Transport & storage	1.10	0.29	0.65	0.36	0.56	1.40
Communications	7.80	16.67	2.18	5.97	10.30	22.21
Financial intermediation	7.94	8.23	11.49	5.53	7.77	9.79
Business services	0.75	15.86	1.35	2.54	7.46	3.87
Social and personal services	2.60	3.23	0.68	0.35	2.24	4.90
Non-market services	0.27	0.73	0.50	0.32	0.49	0.75
Total economy	1.40	3.56	1.83	1.95	2.49	3.37

Table B.16 Share of ICT capital in value added, 1995-2000

	France	Germany	Netherlands	U.K.	EU-4	U.S.
Agriculture, forestry and fishing	0.09	0.25	0.41	1.01	0.33	0.82
Mining and quarrying	0.81	0.23	2.14	0.64	0.89	1.87
Food products	0.99	1.90	2.71	2.39	1.86	3.13
Textiles, clothing and leather	0.80	0.21	1.38	1.59	0.94	2.25
Wood products	0.84	1.15	1.28	1.81	1.20	1.87
Paper, printing and publishing	1.32	4.67	4.17	3.92	3.69	4.96
Petroleum and coal products	2.11	14.80	3.13	0.83	5.01	1.53
Chemical products	2.20	3.36	3.13	3.25	3.01	4.90
Rubber and plastics	1.20	2.62	1.61	1.97	2.04	1.97
Non-metalic mineral products	1.13	1.58	1.68	2.88	1.76	2.22
Metal products	0.98	0.83	2.02	1.25	1.04	2.39
Machinery	1.40	1.59	3.54	3.75	2.07	2.96
Electrical and electronic equipment & instruments	1.31	2.51	5.10	7.48	3.54	9.02
Transport equipment	1.58	1.55	1.79	1.29	1.55	3.05
Furniture and miscellaneous manufacturing	1.59	2.12	0.75	2.72	2.07	3.81
Electricity, gas and water	2.99	2.39	1.47	3.04	2.69	3.81
Construction	0.53	1.05	1.55	1.34	1.06	1.95
Wholesale trade	2.00	3.85	4.04	9.90	5.28	9.53
Retail trade	2.42	3.85	1.66	6.17	3.91	3.96
Hotels and restaurants	2.10	0.06	0.53	0.43	0.86	1.18
Transport & storage	1.98	0.90	1.19	1.79	1.47	3.27
Communications	6.36	18.99	4.87	14.63	13.13	23.79
Financial intermediation	9.15	10.26	14.54	9.54	10.23	15.20
Business services	1.53	8.79	2.67	6.15	5.85	4.25
Social and personal services	3.16	1.81	1.30	0.69	1.74	7.05
Non-market services	0.37	0.60	0.78	0.71	0.57	1.25
Total economy	1.89	3.71	2.88	4.05	3.28	5.22

Table B.17 Decomposition of industry labour productivity growth, France, 1979-1995

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	5.81	0.00	0.01	2.27	3.53
Mining and quarrying	3.71	-0.21	0.11	1.56	2.25
Food products	1.30	0.19	0.12	1.55	-0.57
Textiles, clothing and leather	1.90	0.28	0.06	1.18	0.38
Wood products	3.06	0.21	0.05	0.64	2.16
Paper, printing and publishing	1.93	0.31	0.16	1.67	-0.22
Petroleum and coal products	-5.83	0.03	0.23	2.54	-8.62
Chemical products	4.49	0.34	0.20	1.98	1.98
Rubber and plastics	1.81	0.33	0.09	0.20	1.20
Non-metalic mineral products	4.10	0.22	0.06	0.57	3.24
Metal products	1.72	0.23	0.07	0.81	0.60
Machinery	3.44	0.36	0.15	1.49	1.44
Electrical and electronic equipment & instruments	7.87	0.47	0.17	1.58	5.65
Transport equipment	4.73	0.33	0.09	1.05	3.26
Furniture and miscellaneous manufacturing	3.00	0.22	0.15	1.30	1.33
Electricity, gas and water	4.40	-0.01	0.23	0.88	3.30
Construction	2.28	0.08	0.05	0.68	1.47
Wholesale trade	3.55	0.08	0.13	0.54	2.80
Retail trade	3.36	0.13	0.13	0.51	2.58
Hotels and restaurants	-2.18	0.13	0.17	0.73	-3.20
Transport & storage	2.70	0.19	0.12	0.50	1.89
Communications	5.75	-0.42	0.41	0.80	4.96
Financial intermediation	3.73	0.23	1.18	-0.28	2.60
Business services	1.12	0.19	0.08	-1.57	2.42
Social and personal services	-2.52	0.29	0.14	-1.04	-1.92
Non-market services	1.51	0.25	0.03	-0.06	1.29

Table B.18 Decomposition of industry labour productivity growth, France, 1995-2000

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	4.88	0.00	0.03	2.11	2.73
Mining and quarrying	14.28	2.30	0.20	0.58	11.20
Food products	-0.83	0.32	0.17	-0.41	-0.91
Textiles, clothing and leather	4.30	0.27	0.21	1.34	2.49
Wood products	3.05	-0.12	0.22	0.78	2.16
Paper, printing and publishing	2.56	0.00	0.28	0.66	1.61
Petroleum and coal products	-0.28	0.29	0.38	1.58	-2.53
Chemical products	5.64	0.42	0.55	1.82	2.84
Rubber and plastics	3.30	0.52	0.33	0.49	1.95
Non-metalic mineral products	3.38	-0.19	0.34	1.24	2.00
Metal products	1.35	0.07	0.17	0.08	1.03
Machinery	3.12	0.26	0.30	0.61	1.94
Electrical and electronic equipment & instruments	10.09	0.25	0.25	0.17	9.41
Transport equipment	5.71	0.44	0.30	0.22	4.75
Furniture and miscellaneous manufacturing	2.36	0.14	0.30	-0.14	2.06
Electricity, gas and water	3.72	0.41	0.82	0.14	2.34
Construction	-1.44	0.30	0.09	-0.06	-1.77
Wholesale trade	0.39	0.51	0.30	-0.11	-0.31
Retail trade	1.66	0.62	0.33	-0.02	0.73
Hotels and restaurants	1.14	0.12	0.28	0.24	0.50
Transport & storage	0.87	0.39	0.26	-0.40	0.62
Communications	8.44	0.54	0.62	-0.08	7.36
Financial intermediation	0.20	0.05	1.66	-0.19	-1.32
Business services	-0.26	0.43	0.18	-2.22	1.35
Social and personal services	-0.77	0.47	0.35	-0.98	-0.61
Non-market services	0.98	0.57	0.04	0.01	0.35

Table B.19 Decomposition of industry labour productivity growth, Germany, 1979-1995

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	5.21	0.00	0.01	0.28	4.92
Mining and quarrying	2.62	0.23	0.10	0.67	1.63
Food products	1.92	0.27	0.23	0.54	0.88
Textiles, clothing and leather	3.18	0.33	0.04	1.25	1.56
Wood products	2.03	0.36	0.11	-0.07	1.64
Paper, printing and publishing	1.80	0.24	0.52	0.91	0.13
Petroleum and coal products	-1.58	0.23	1.67	0.00	-3.47
Chemical products	3.94	0.29	0.47	0.29	2.90
Rubber and plastics	2.07	0.28	0.28	0.28	1.23
Non-metalic mineral products	2.86	0.20	0.17	0.83	1.66
Metal products	2.41	0.25	0.07	0.17	1.93
Machinery	1.64	0.45	0.25	0.35	0.59
Electrical and electronic equipment & instruments	4.99	0.54	0.39	0.74	3.76
Transport equipment	2.06	0.28	0.42	0.71	0.65
Furniture and miscellaneous manufacturing	0.26	0.32	0.25	0.81	-1.13
Electricity, gas and water	1.70	0.17	0.24	1.32	-0.03
Construction	-0.45	0.20	0.08	-0.36	-0.36
Wholesale trade	2.04	0.23	0.27	0.00	1.54
Retail trade	1.97	0.22	0.30	0.14	1.31
Hotels and restaurants	-1.65	0.50	0.01	-0.04	-2.11
Transport & storage	3.15	0.12	0.02	0.06	2.94
Communications	5.86	0.55	1.60	1.72	1.99
Financial intermediation	2.67	0.16	1.30	0.89	0.32
Business services	1.46	0.13	1.49	1.78	-1.94
Social and personal services	0.65	0.18	0.17	1.03	-0.73
Non-market services	0.91	0.32	0.07	0.35	0.17

Table B.20 Decomposition of industry labour productivity growth, Germany, 1995-2000

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	6.01	0.00	0.05	0.63	5.33
Mining and quarrying	-2.90	0.18	0.04	0.23	-3.34
Food products	0.83	0.03	0.26	-0.33	0.87
Textiles, clothing and leather	2.84	0.16	0.03	0.61	2.04
Wood products	2.47	0.05	0.23	0.76	1.43
Paper, printing and publishing	3.27	0.09	0.89	1.24	1.05
Petroleum and coal products	12.28	0.10	-0.71	1.18	11.71
Chemical products	2.67	0.13	0.55	0.87	1.12
Rubber and plastics	1.09	-0.14	0.34	0.43	0.46
Non-metalic mineral products	1.26	0.08	0.27	0.64	0.27
Metal products	1.41	0.08	0.11	0.19	1.03
Machinery	1.16	0.11	0.17	0.06	0.81
Electrical and electronic equipment & instruments	8.94	0.37	0.35	-0.15	8.50
Transport equipment	-3.12	0.14	0.14	-0.16	-3.24
Furniture and miscellaneous manufacturing	1.19	0.11	0.29	0.51	0.28
Electricity, gas and water	6.38	0.03	0.61	2.90	2.84
Construction	1.12	0.03	0.21	0.11	0.77
Wholesale trade	1.76	0.12	0.64	0.10	0.89
Retail trade	1.13	-0.01	0.67	0.24	0.23
Hotels and restaurants	-4.21	0.09	0.01	-0.13	-4.17
Transport & storage	4.03	0.04	0.24	0.09	3.67
Communications	17.25	0.19	1.84	2.08	13.15
Financial intermediation	4.59	0.07	1.71	0.52	2.29
Business services	-0.75	0.03	1.14	-0.27	-1.65
Social and personal services	-0.03	0.04	0.28	0.26	-0.61
Non-market services	0.64	-0.04	0.09	0.23	0.36

Table B.21 Decomposition of industry labour productivity growth, Netherlands, 1979-1995

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	4.25	0.00	0.04	1.07	3.14
Mining and quarrying	-2.65	0.01	0.24	0.62	-3.52
Food products	4.20	0.08	0.27	1.10	2.75
Textiles, clothing and leather	4.04	0.09	0.10	0.38	3.46
Wood products	5.32	0.10	0.08	0.43	4.71
Paper, printing and publishing	3.23	0.03	0.53	1.04	1.62
Petroleum and coal products	5.62	0.06	0.71	2.99	1.87
Chemical products	4.72	0.10	0.56	1.25	2.80
Rubber and plastics	4.09	0.12	0.17	0.07	3.73
Non-metalic mineral products	3.41	0.07	0.23	1.44	1.67
Metal products	2.44	0.06	0.48	0.60	1.30
Machinery	3.01	0.07	0.31	0.12	2.51
Electrical and electronic equipment & instruments	9.13	0.06	0.38	0.54	8.59
Transport equipment	5.02	0.08	0.19	0.46	4.30
Furniture and miscellaneous manufacturing	3.16	0.10	0.05	0.08	2.93
Electricity, gas and water	2.22	0.02	0.14	1.39	0.67
Construction	2.01	0.04	0.15	0.46	1.36
Wholesale trade	2.21	0.11	0.58	0.29	1.23
Retail trade	2.17	0.11	0.14	0.21	1.70
Hotels and restaurants	-0.64	0.10	0.06	0.28	-1.09
Transport & storage	1.90	0.03	0.12	0.34	1.42
Communications	2.48	0.04	0.48	1.26	0.69
Financial intermediation	1.65	0.15	2.39	1.06	-1.95
Business services	0.04	0.08	0.20	-0.50	0.26
Social and personal services	1.33	-0.01	0.13	1.17	0.03
Non-market services	1.14	0.15	0.09	0.24	0.66

Table B.22 Decomposition of industry labour productivity growth, Netherlands, 1995-2000

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	2.68	-0.04	0.13	0.84	1.75
Mining and quarrying	3.08	0.02	0.51	3.54	-0.99
Food products	1.46	0.19	0.47	0.60	0.20
Textiles, clothing and leather	7.90	0.14	0.33	1.03	6.41
Wood products	2.58	0.14	0.37	0.89	1.17
Paper, printing and publishing	3.71	0.07	1.07	0.70	1.86
Petroleum and coal products	-11.37	0.11	-0.23	3.02	-14.26
Chemical products	4.08	0.15	0.17	1.81	1.95
Rubber and plastics	4.19	0.22	0.30	0.37	3.30
Non-metalic mineral products	4.48	0.10	0.46	1.34	2.57
Metal products	1.98	0.12	0.41	0.26	1.19
Machinery	3.44	0.13	0.80	0.18	2.33
Electrical and electronic equipment & instruments	-1.69	0.12	1.10	0.15	-2.92
Transport equipment	5.10	0.14	0.32	-0.71	5.36
Furniture and miscellaneous manufacturing	2.26	0.16	0.23	0.26	1.61
Electricity, gas and water	3.73	-0.01	0.31	4.27	-0.84
Construction	0.15	0.04	0.43	0.47	-0.79
Wholesale trade	4.67	0.03	0.81	0.05	3.77
Retail trade	2.04	0.03	0.51	0.33	1.18
Hotels and restaurants	0.87	-0.04	0.14	-0.54	1.30
Transport & storage	2.90	0.14	0.22	0.25	2.29
Communications	8.23	0.38	1.30	1.68	4.87
Financial intermediation	-0.02	0.42	2.91	0.34	-3.69
Business services	1.02	0.44	0.57	-0.33	0.34
Social and personal services	-0.26	-0.18	0.28	-0.47	0.11
Non-market services	0.52	0.12	0.18	0.04	0.19

Table B.23 Decomposition of industry labour productivity growth, U.K., 1979-1995

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	3.05	0.18	0.08	0.60	2.19
Mining and quarrying	11.99	0.23	0.13	9.79	1.84
Food products	3.24	0.50	0.40	0.87	1.47
Textiles, clothing and leather	3.15	0.33	0.10	0.62	2.10
Wood products	-0.11	0.30	0.09	-0.25	-0.24
Paper, printing and publishing	2.38	0.09	0.31	0.80	1.18
Petroleum and coal products	2.50	0.58	0.25	1.09	0.58
Chemical products	6.21	0.42	0.32	1.11	4.35
Rubber and plastics	2.78	0.32	0.18	0.44	1.84
Non-metalic mineral products	3.34	0.28	0.85	1.79	0.42
Metal products	3.43	0.47	0.11	0.32	2.53
Machinery	2.13	0.31	0.21	0.36	1.25
Electrical and electronic equipment & instruments	12.56	0.53	0.57	1.19	10.71
Transport equipment	6.04	0.24	0.16	0.58	5.05
Furniture and miscellaneous manufacturing	0.56	0.32	0.19	0.93	-0.88
Electricity, gas and water	5.20	0.25	0.42	2.54	1.99
Construction	2.41	0.12	0.13	0.10	2.06
Wholesale trade	3.04	0.39	0.99	0.68	0.98
Retail trade	1.81	0.68	0.62	1.04	-0.53
Hotels and restaurants	-0.23	0.83	0.08	0.89	-2.03
Transport & storage	3.81	1.42	0.10	0.39	1.91
Communications	4.87	0.42	0.75	1.25	2.45
Financial intermediation	0.39	0.31	1.26	0.75	-1.93
Business services	1.14	0.10	0.65	1.35	-0.97
Social and personal services	2.64	0.95	0.04	0.51	1.14
Non-market services	0.19	0.75	0.07	0.17	-0.79

Table B.24 Decomposition of industry labour productivity growth, U.K., 1995-2000

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	2.94	0.21	0.10	0.78	1.84
Mining and quarrying	1.24	0.12	-0.03	-1.08	2.22
Food products	-0.79	0.30	0.11	-0.06	-1.15
Textiles, clothing and leather	1.48	0.56	0.51	0.86	-0.45
Wood products	-0.68	0.15	0.54	0.13	-1.51
Paper, printing and publishing	0.15	0.34	0.66	-0.43	-0.41
Petroleum and coal products	-4.82	0.29	-0.02	-1.60	-3.49
Chemical products	3.94	0.69	0.70	0.93	1.62
Rubber and plastics	0.51	0.42	0.47	0.36	-0.75
Non-metalic mineral products	1.30	0.17	0.31	1.21	-0.39
Metal products	1.49	0.14	0.31	0.34	0.70
Machinery	-0.04	0.20	0.92	-0.11	-1.06
Electrical and electronic equipment & instruments	15.68	0.41	1.43	0.95	13.02
Transport equipment	0.13	0.51	0.14	0.31	-0.84
Furniture and miscellaneous manufacturing	0.19	0.16	0.65	1.14	-1.76
Electricity, gas and water	11.08	0.19	0.51	5.98	4.41
Construction	1.23	0.30	0.07	0.57	0.29
Wholesale trade	4.70	0.19	2.12	0.21	2.18
Retail trade	2.88	0.32	0.81	0.72	1.04
Hotels and restaurants	-2.68	0.45	0.02	1.26	-4.41
Transport & storage	5.60	0.01	0.32	0.30	4.97
Communications	9.74	0.67	3.08	0.19	5.79
Financial intermediation	3.64	0.50	1.11	-0.53	2.56
Business services	2.75	0.63	1.35	0.04	0.74
Social and personal services	0.97	0.44	0.11	0.03	0.39
Non-market services	1.06	0.65	0.06	0.22	0.13

Table B.25 Decomposition of industry labour productivity growth, EU-4, 1979-1995

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	5.08	-0.05	0.02	1.39	3.73
Mining and quarrying	7.00	0.26	0.16	5.82	0.76
Food products	2.31	0.30	0.24	0.98	0.79
Textiles, clothing and leather	2.72	0.30	0.07	1.00	1.36
Wood products	2.02	0.23	0.09	0.14	1.56
Paper, printing and publishing	2.16	0.23	0.39	1.08	0.45
Petroleum and coal products	-1.74	0.11	0.64	1.54	-4.03
Chemical products	4.76	0.43	0.39	0.99	2.94
Rubber and plastics	2.22	0.40	0.21	0.27	1.35
Non-metalic mineral products	3.40	0.28	0.27	1.12	1.72
Metal products	2.65	0.49	0.11	0.49	1.56
Machinery	2.25	0.51	0.24	0.60	0.91
Electrical and electronic equipment & instruments	7.33	0.61	0.39	1.09	5.69
Transport equipment	4.04	0.55	0.34	1.03	1.85
Furniture and miscellaneous manufacturing	1.35	0.30	0.20	0.92	-0.08
Electricity, gas and water	3.46	0.19	0.28	1.62	1.36
Construction	1.18	0.16	0.09	0.16	0.77
Wholesale trade	2.64	0.19	0.42	0.34	1.69
Retail trade	2.30	0.29	0.31	0.45	1.25
Hotels and restaurants	-1.39	0.43	0.09	0.51	-2.42
Transport & storage	3.19	0.52	0.08	0.37	2.23
Communications	5.41	0.26	0.91	1.29	2.95
Financial intermediation	2.03	0.13	1.35	0.53	0.03
Business services	1.28	0.14	0.87	0.57	-0.30
Social and personal services	0.45	0.29	0.15	0.55	-0.54
Non-market services	0.96	0.37	0.06	0.18	0.35

Table B.26 Decomposition of industry labour productivity growth, EU-4, 1995-2000

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	4.72	-0.02	0.06	1.43	3.26
Mining and quarrying	4.98	0.29	0.13	3.21	1.35
Food products	0.02	0.19	0.22	-0.20	-0.19
Textiles, clothing and leather	3.13	0.28	0.27	1.06	1.52
Wood products	2.00	0.02	0.29	0.65	1.04
Paper, printing and publishing	2.09	0.20	0.69	0.48	0.73
Petroleum and coal products	-0.43	0.10	-0.08	0.20	-0.65
Chemical products	3.92	0.35	0.55	1.29	1.74
Rubber and plastics	1.63	0.02	0.38	0.49	0.73
Non-metalic mineral products	2.06	0.08	0.32	1.00	0.66
Metal products	1.57	0.14	0.19	0.30	0.93
Machinery	1.50	0.21	0.37	0.18	0.74
Electrical and electronic equipment & instruments	10.48	0.27	0.62	0.28	9.45
Transport equipment	-0.16	0.41	0.20	-0.05	-0.62
Furniture and miscellaneous manufacturing	1.24	0.10	0.41	0.62	0.11
Electricity, gas and water	6.63	0.07	0.60	2.97	2.99
Construction	0.47	0.11	0.16	0.22	-0.03
Wholesale trade	2.46	0.15	1.02	0.09	1.20
Retail trade	1.71	0.15	0.60	0.31	0.65
Hotels and restaurants	-1.90	0.14	0.10	0.38	-2.52
Transport & storage	3.59	0.02	0.27	0.09	3.20
Communications	11.43	0.50	1.61	0.71	8.63
Financial intermediation	2.79	0.19	1.65	0.01	0.94
Business services	0.59	0.27	0.94	-0.53	-0.09
Social and personal services	-0.06	0.23	0.25	-0.22	-0.32
Non-market services	0.86	0.31	0.08	0.15	0.32

Table B.27 Decomposition of industry labour productivity growth, U.S., 1979-1995

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	4.93	0.16	0.06	-0.25	4.97
Mining and quarrying	4.59	0.07	0.26	2.72	1.54
Food products	1.95	0.27	0.32	0.55	0.80
Textiles, clothing and leather	3.22	0.50	0.22	0.35	2.15
Wood products	0.84	0.26	0.22	-0.42	0.77
Paper, printing and publishing	-0.92	0.27	0.48	0.28	-1.95
Petroleum and coal products	6.51	0.18	0.24	2.10	3.99
Chemical products	3.24	0.24	0.50	0.83	1.67
Rubber and plastics	4.23	0.40	0.15	0.12	3.57
Non-metalic mineral products	2.01	0.31	0.15	0.06	1.49
Metal products	1.94	0.22	0.18	0.22	1.33
Machinery	-0.35	0.40	0.51	0.21	-1.47
Electrical and electronic equipment & instruments	12.54	0.76	1.03	0.95	9.80
Transport equipment	0.88	0.35	0.26	0.06	0.20
Furniture and miscellaneous manufacturing	2.33	0.29	0.31	0.16	1.57
Electricity, gas and water	1.33	0.17	0.46	0.74	-0.04
Construction	-0.41	0.08	0.10	-0.33	-0.27
Wholesale trade	2.29	0.21	1.04	0.52	0.52
Retail trade	2.51	0.14	0.52	0.51	1.34
Hotels and restaurants	-1.07	0.05	0.09	0.06	-1.28
Transport & storage	1.31	0.26	0.14	-0.46	1.37
Communications	1.70	0.37	0.89	0.72	-0.28
Financial intermediation	0.06	0.43	1.67	1.25	-3.29
Business services	0.05	0.36	0.49	-0.56	-0.25
Social and personal services	1.14	0.62	0.43	0.17	-0.09
Non-market services	-0.55	0.25	0.11	0.11	-1.02

Table B.28 Decomposition of industry labour productivity growth, U.S., 1995-2000

	Labour productivity growth	*Contribution of:* Labour quality growth	ICT capital deepening	Non-ICT capital deepening	TFP growth
Agriculture, forestry and fishing	10.35	0.13	0.13	1.27	8.81
Mining and quarrying	0.36	-0.02	0.28	2.01	-1.90
Food products	-6.00	0.00	0.46	0.82	-7.28
Textiles, clothing and leather	2.90	0.19	0.42	1.25	1.05
Wood products	-0.90	0.21	0.29	0.15	-1.54
Paper, printing and publishing	1.10	0.21	0.91	0.41	-0.44
Petroleum and coal products	4.54	0.17	0.08	0.73	3.56
Chemical products	2.40	0.17	0.76	1.50	-0.03
Rubber and plastics	4.75	0.03	0.37	1.08	3.27
Non-metalic mineral products	1.22	0.19	0.49	1.13	-0.59
Metal products	1.37	0.21	0.34	-0.11	0.93
Machinery	-0.12	0.35	0.57	0.09	-1.13
Electrical and electronic equipment & instruments	21.73	0.26	1.59	1.25	18.63
Transport equipment	1.34	0.41	0.41	0.25	0.26
Furniture and miscellaneous manufacturing	3.65	0.20	0.57	0.25	2.63
Electricity, gas and water	2.32	0.11	0.33	1.66	0.22
Construction	-0.06	0.16	0.34	0.29	-0.84
Wholesale trade	7.19	0.15	1.78	0.37	4.89
Retail trade	6.62	0.08	0.69	0.56	5.30
Hotels and restaurants	0.20	0.02	0.14	0.39	-0.36
Transport & storage	2.53	0.20	0.50	0.39	1.44
Communications	5.93	0.23	1.90	0.82	2.99
Financial intermediation	4.99	0.15	3.05	0.91	0.88
Business services	-0.60	0.22	0.72	-0.53	-1.02
Social and personal services	-1.65	0.30	1.05	0.50	-3.50
Non-market services	-0.61	0.35	0.19	0.17	-1.32

Figure B.1, Industry contributions to aggregate labour productivity growth, EU-4 and U.S., 1995-2000

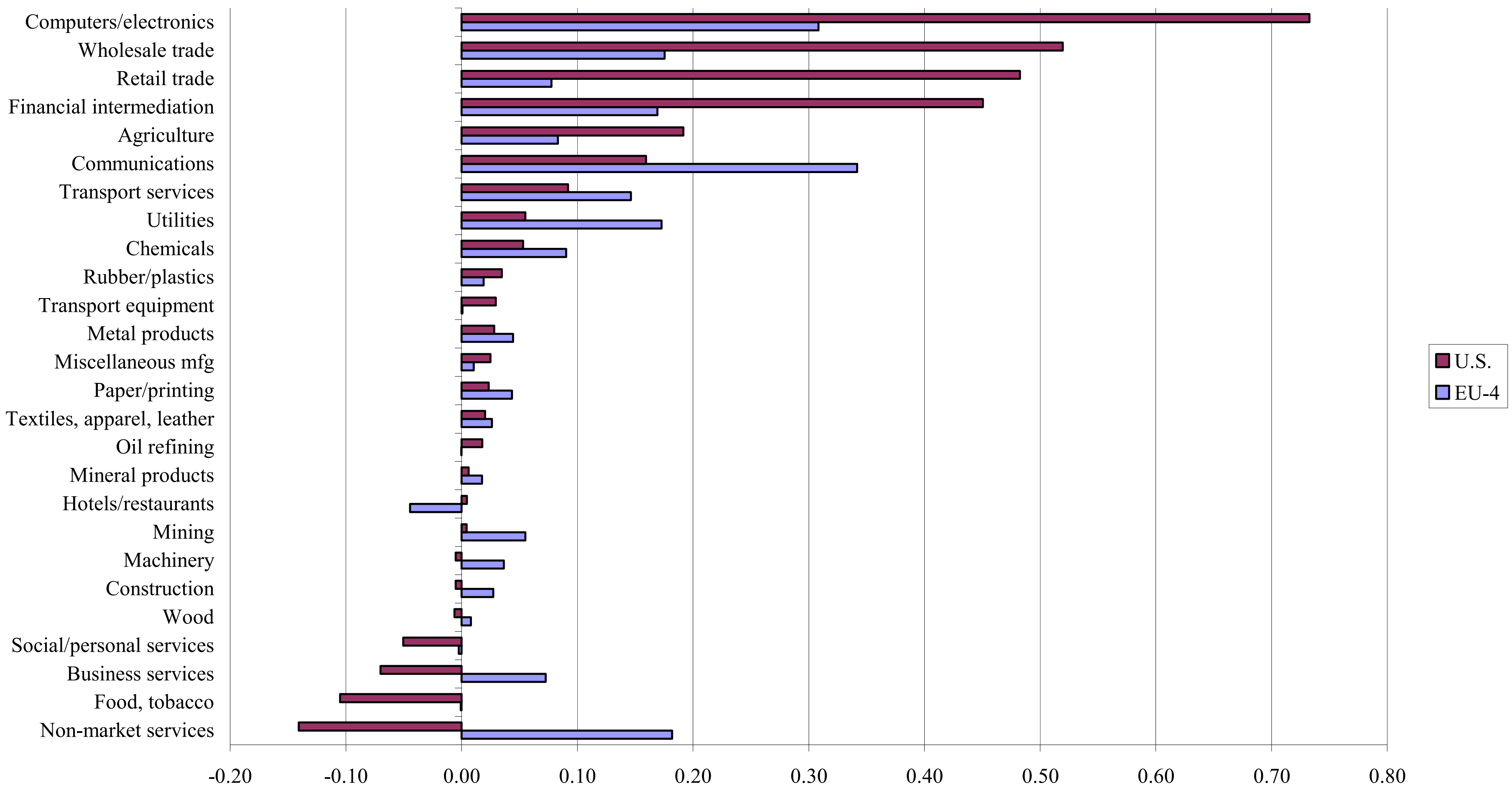


Figure B.2, Contributions to aggregate labour productivity growth of industry labour quality growth, EU-4 and U.S., 1995-2000

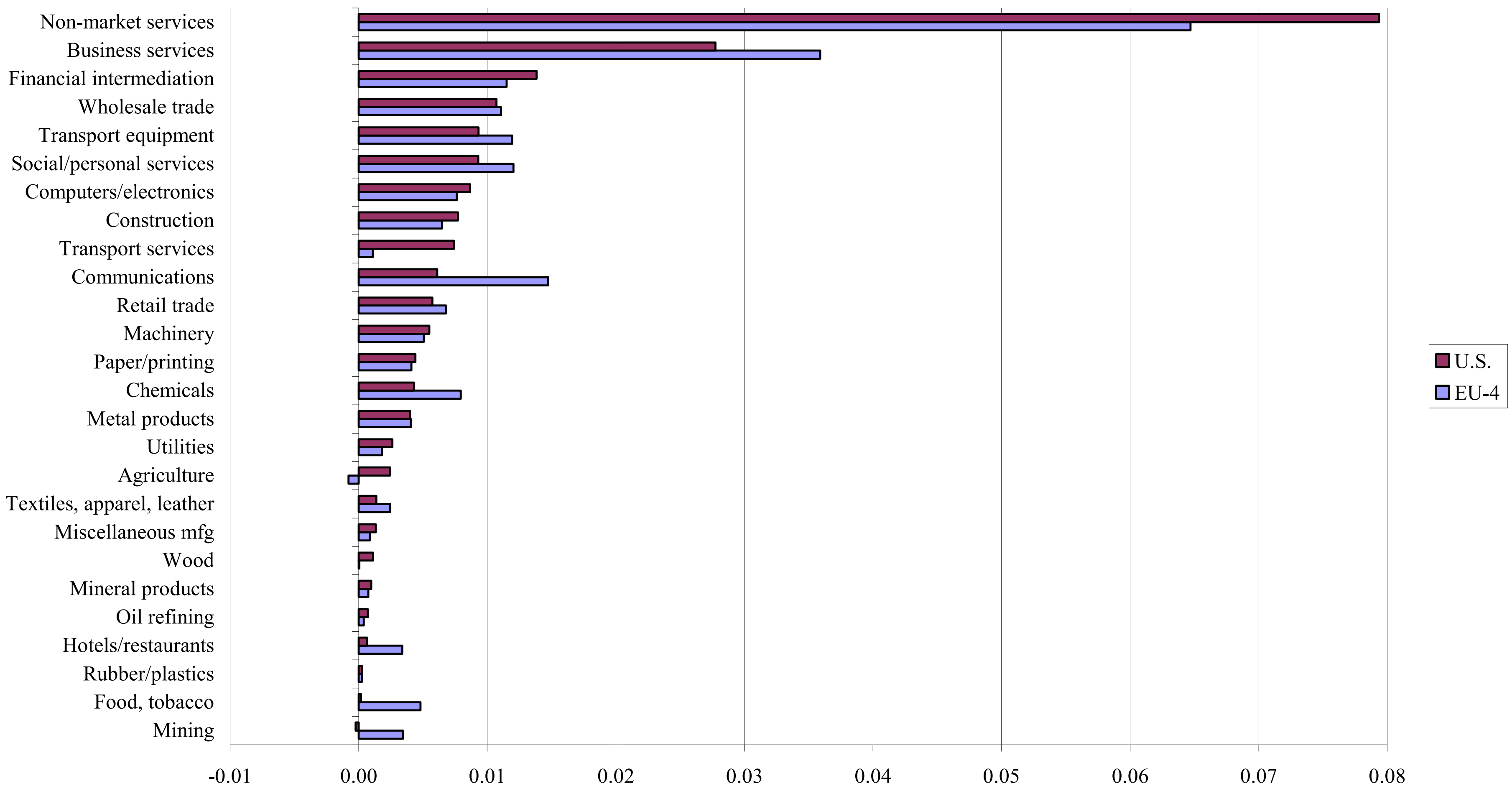


Figure B.3, Contributions to aggregate labour productivity growth of industry ICT-capital deepening, EU-4 and U.S., 1995-2000

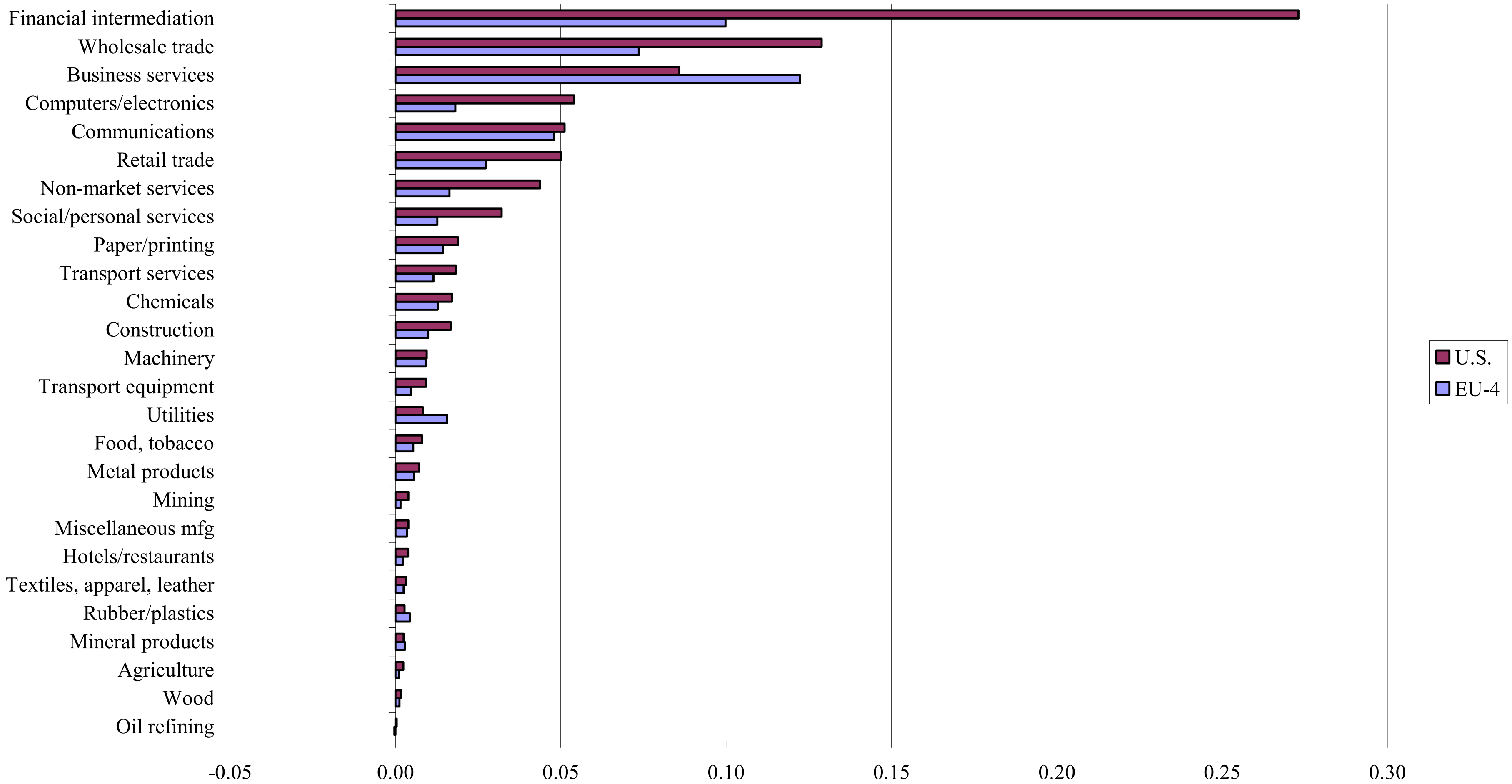


Figure B.4, Contributions to aggregate labour productivity growth of non-ICT capital deepening, EU-4 and U.S., 1995-2000

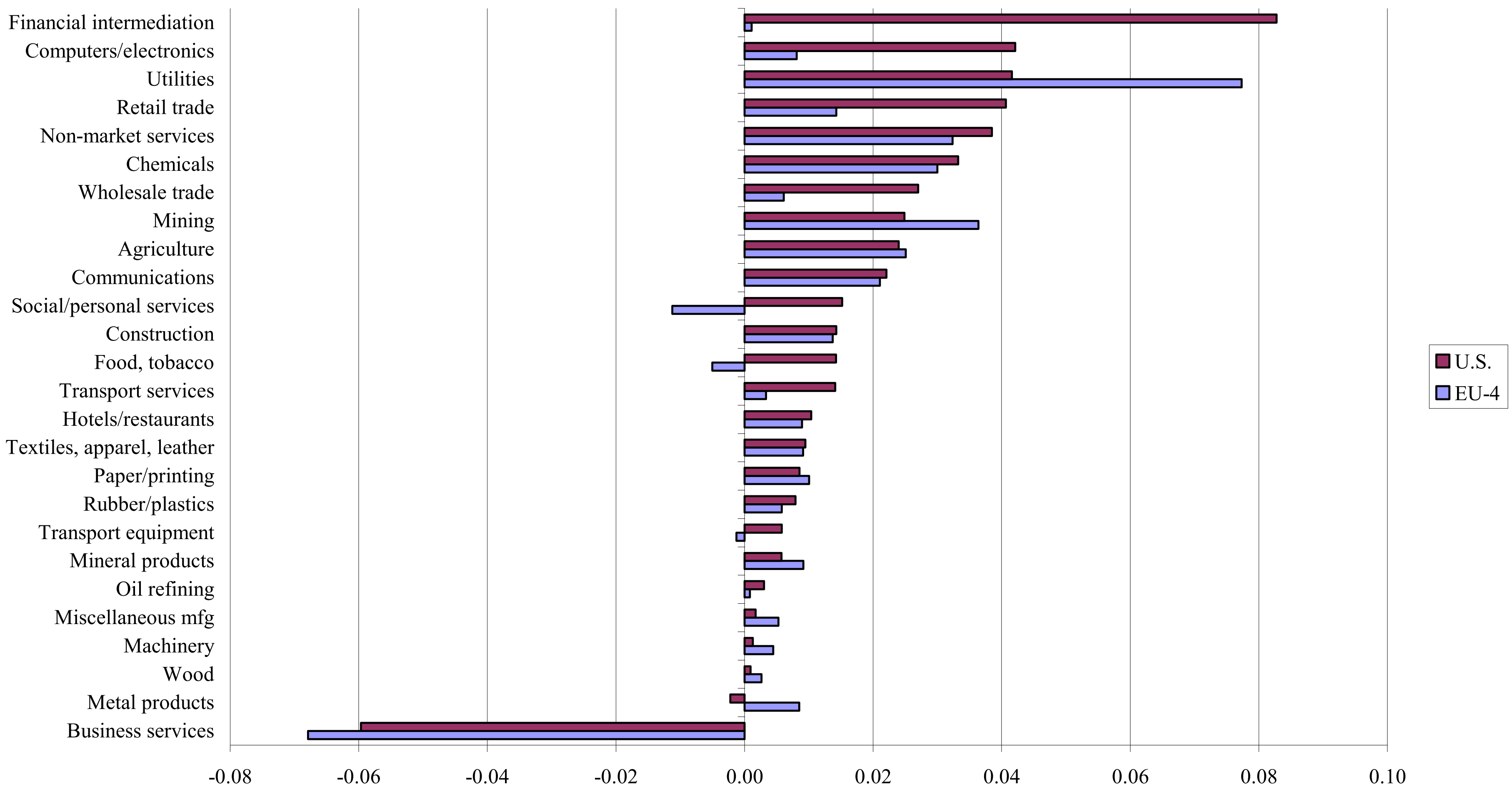


Figure B.5, Contributions to aggregate labour productivity growth of industry TFP growth, EU-4 and U.S., 1995-2000

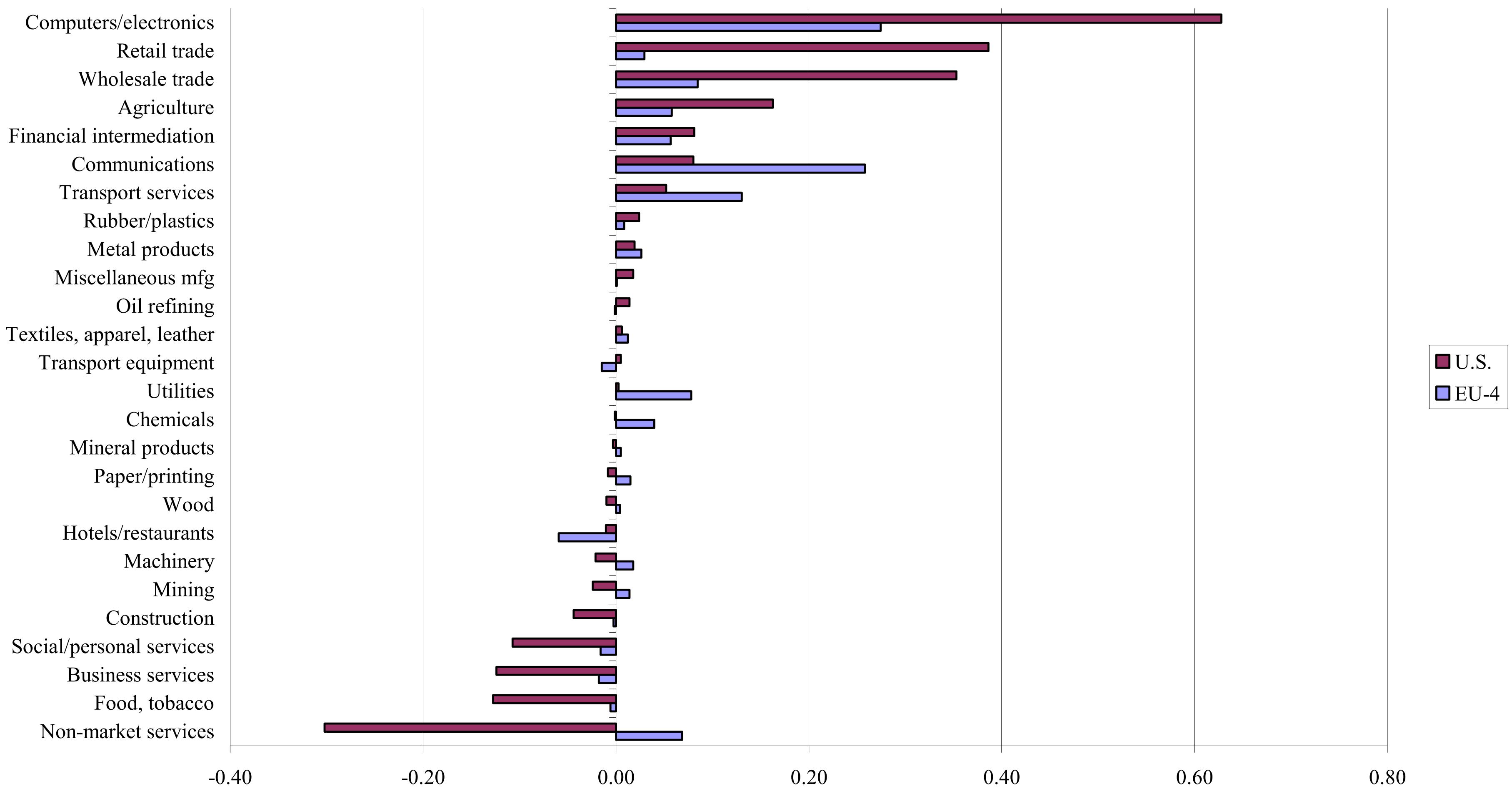


Figure B.6, Industry contributions to aggregate ICT capital deepening, EU-4 and U.S., 1995-2000

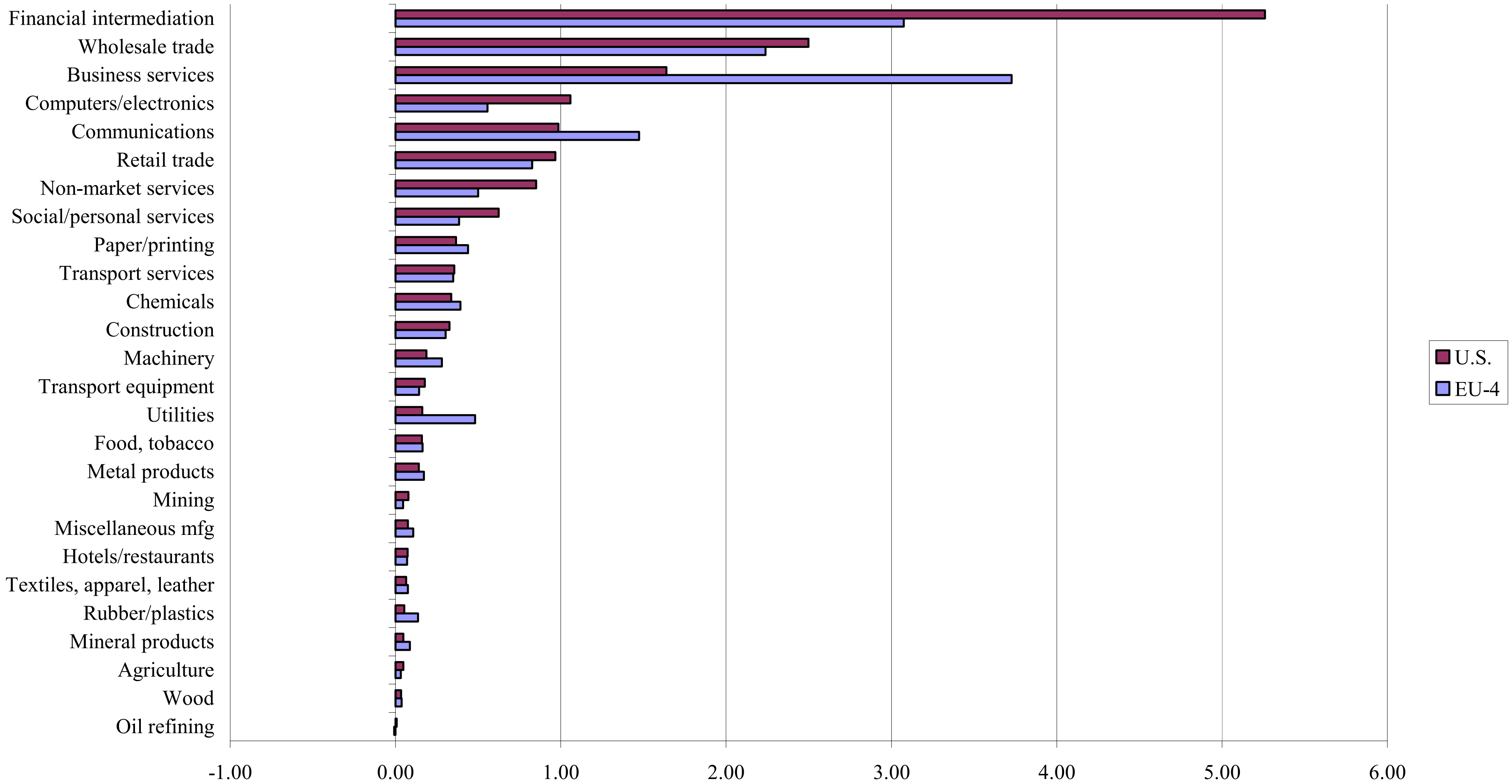


Figure B.7, Industry contributions to aggregate non-ICT capital deepening, EU-4 and U.S., 1995-2000

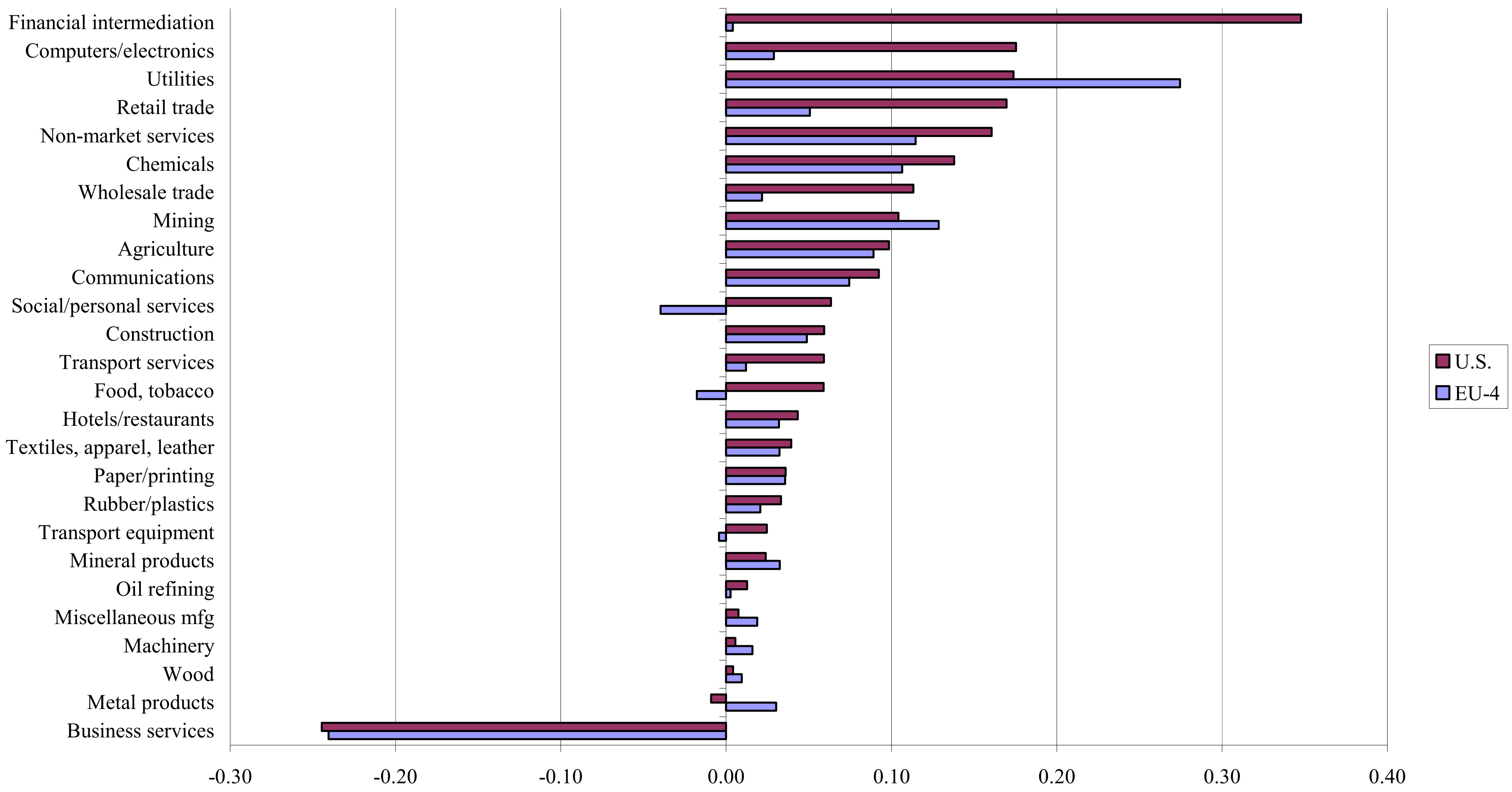
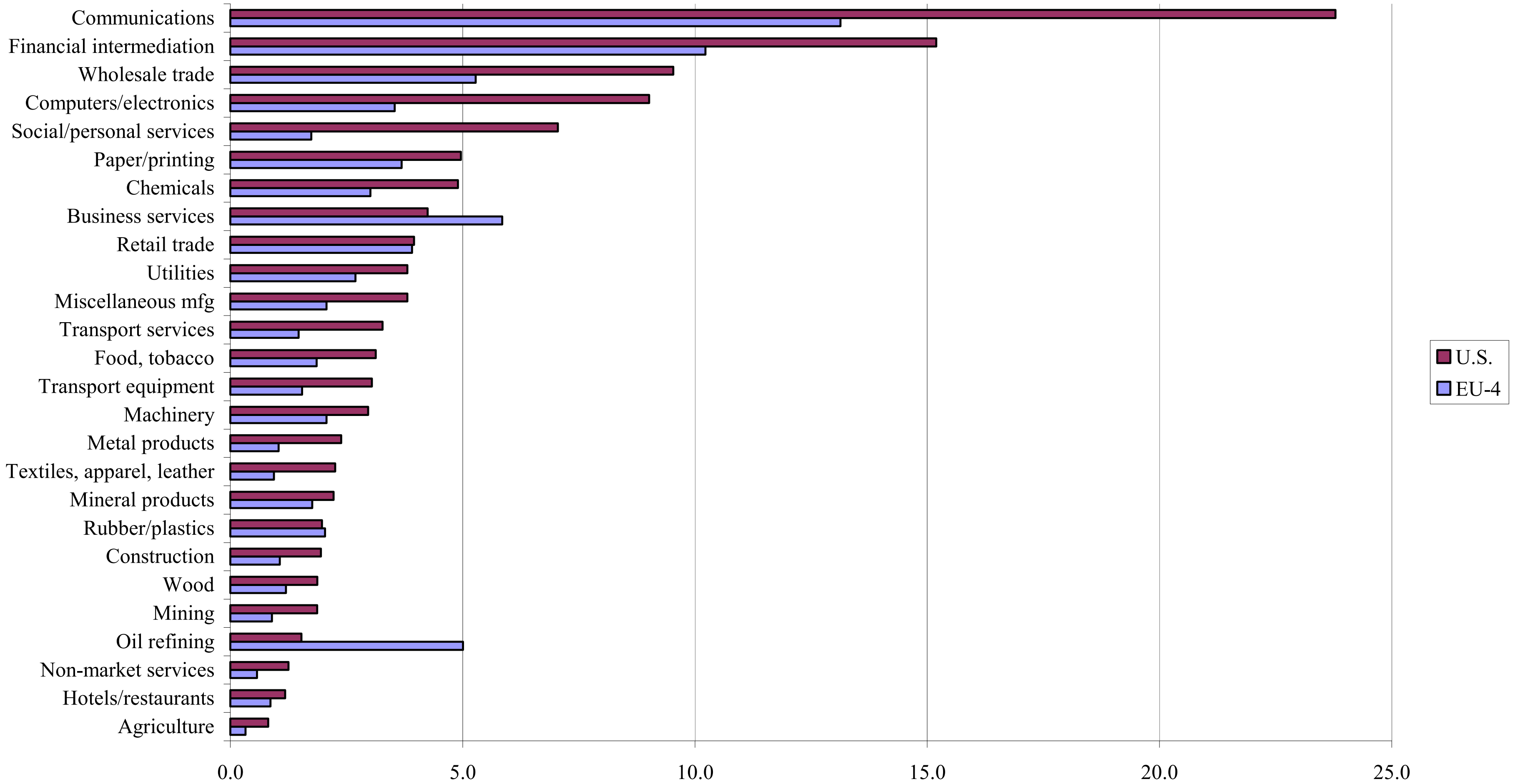


Figure B.8, Share of ICT capital in value added, EU-4 and U.S., 1995-2000



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